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〈論文〉

A Recurrent Network Model of Cognitive Consistency: How Balance and Dissonance Theories Could Be Unified

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Abstract

A recurrent network model of cognitive consistency is proposed in an attempt to unify Heiderian balance theories and the original theory and revised versions of cognitive dissonance. An element in a cognitive field consists of a processing unit, a node as a set of units, or a sentence as a set of nodes, in the present model. The cognitive element can be expressed as an isomorphic semi-sphere. The levels of activation of the cognitive elements are expressed by the semi-spheres, whose volumes correspond to the values of activation. Cognitive elements send and receive activation between each other by means of bidirectional weighted connections. Typical situations related to balance and dissonance theories were discussed in terms of the recurrent network model. The status of cultural differences in cognitive consistency was also examined. This model is expected to be helpful to understand the apparently different theories from the same point of view.

Keywords: recurrent network, cognitive consistency, balance theory, dissonance theory

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Introduction

Since theories of cognitive consistency appeared in the middle of the 20th century (for an inclusive review, see Abelson et al., 1968; Gawronski & Strack, 2012), there have been two apparently different kinds of studies in terms of the conception and definition of cognitive consistency.

One is a flow of research in Heider's (1946, 1958) balance theory and the subsequent theories with the concept of balance (Abelson & Rosenberg, 1958; Cartwright & Harary, 1956; Greenwald et al., 2002; Newcomb, 1953: Osgood & Tannenbaum, 1955; Read & Simon, 2012; Rosenberg, 1956, 1960; Rosenberg & Abelson, 1960; Tannenbaum, 1967, 1968).

Another is a flow of research in Festinger's (1957) original theory of cognitive dissonance and its revised versions (E. Aronson, 1968, 1992, 1999; Beauvois & Joule, 1996; Cooper & Fazio, 1984; Festinger, 1964; Gawronski, Peters, & Strack, 2008; Harmon-Jones & Mills, 1999; Harmon-Jones, Amodio, & Harmon-Jones, 2009; Sakai, 1999; Stone, 2012).

A recurrent network model of cognitive consistency is proposed with a view to unifying Heiderian balance and Festingerian dissonance theories, using the terms of connectionist multi-module network modeling and parallel constraint satisfaction processing (Smith, 1998).

Fundamental Assumptions

An element in a cognitive field is defined as a simple processing unit (like a pixel), a node as a set of units, and a sentence as a set of nodes, in the present recurrent network model of cognitive consistency. A concept or object is expressed by a semi-sphere of an activated node that is an output pattern of activation across a set of processing units in a module. A sentence is also expressed by a semi-sphere of a representation that is an output pattern of activation across a set of nodes in related modules. Therefore, activation of every cognitive element can be expressed as an isomorphic semi-sphere.

Contraction and Expansion of Semi-spheres and Connection Weights

The levels of positive and negative activation of the cognitive elements at any particular moment are expressed respectively by convex and concave semi-spheres. The volume of the semi-sphere is defined as the absolute value of activation of the corresponding cognitive element. Cognitive elements send and receive activation between each other by means of bidirectional weighted connections. The values of connection weights between any two cognitive elements can be either positive or negative, --- or, if no activation is sent or received by the cognitive elements, the values of connection weights are equal to zero.

Once each cognitive element is activated by sensory inputs or by other networks, it struggles against contraction of its volume, and at the same time, struggles for expansion. The recurrent network is therefore in an inconsistent state at a particular moment if any two semi-spheres are simultaneously contracting because of the flow of activation between the cognitive elements, whereas, if all semi-spheres are expanding, the network is in a consistent state.

The matrix structure of the values of connection weights between four activated cognitive elements is shown in Table 1. It is not always necessary for the matrix of the recurrent network model to be symmetric. Each semi-sphere is assumed to have a particular coefficient of contraction and a particular coefficient of expansion. Each connection weight is in itself assumed to have a particular coefficient of change corresponding to its resistance to change.

Nature of Unit Semi-sphere Recurrent Network

When the recurrent network model is applied to the network of activated processing units, the semi-spheres are assumed to have large coefficients of contraction and expansion so that their volumes change quickly. The connection weights are assumed to be results of learning, and because of their high resistance to change, they change slowly. The final output pattern of activation in the unit semi-sphere recurrent network is an automatic simultaneous solution of the two kinds of restrictions from (a) the current input pattern (e.g., external stimuli) and (b) the learned connection weights.

Table 1.

Matrix Expression of the Connection Weights in a Recurrent Network With Four Units.

Activation of sending unit a_i (U_i)	Activation of receiving unit a_j (U_j) a_1 (U_1)	a_2 (U_2)	a_3 (U_3)	a_4 (U_4)
a_1 (U_1)	w_{11}	w_{12}	w_{13}	w_{14}
a_2 (U_2)	w_{21}	w_{22}	w_{23}	w_{24}
a_3 (U_3)	w_{31}	w_{32}	w_{33}	w_{34}
a_4 (U_4)	w_{41}	w_{42}	w_{43}	w_{44}

Note. The symbols a_i (U_i) and a_j (U_j) represent respectively the levels of activation of unit *i* (*i* = 1 to 4) and unit *j* (*j* = 1 to 4). W_{ij} denotes a connection weight from sending unit U_i to receiving unit U_j. The value of connection weight can be assumed: $-1 \leqq w_{ij} \leqq 1$.

Nature of Node or Sentence Semi-sphere Recurrent Network

By contrast, when the recurrent network model is applied to the network of activated nodes or sentences, the volumes of the semi-spheres are assumed to be able to change quickly or slowly, according to the coefficients of contraction and expansion of the corresponding cognitive elements. The connection weights are assumed to be results of perception and learning. The perceptual weights change quickly and the learned weights change slowly.

The level of activation of a node in the recurrent network model can be measured by the evaluation or perceived reality of the corresponding concept or object. In line with Festinger's (1957) discussion of cognitive elements, the level of activation of a sentence in the recurrent network model is defined as the importance of the corresponding cognitive element and can be measured by the perceived importance of the sentence which depends upon its perceived reality and evaluation. Therefore, it should be noted that the values of activation of sentences are always positive and the recurrent network includes only convexes.

The final output pattern of activation in the node or sentence semi-sphere network may be a consciously controlled simultaneous solution, an automatic simultaneous solution, or an interactive solution, of the three kinds of restrictions from (a) the current input pattern, (b) the coefficients of contraction and expansion, and (c) the perceptual or learned connection weights.

Application to Heiderian Balance Theories

A typical imbalanced state discussed by Heider (1946, 1958) is shown in Figure 1: Mr. A has observed his beloved wife wearing a blue sweater and he dislikes blue sweaters very much. In terms of the recurrent network model, the positively activated node of his wife is sending positive activation via a positive connection to the negatively activated node of the blue sweater, so that the semi-sphere of the blue sweater is in contraction. On the other hand, the negatively activated node of the blue sweater is sending negative activation via a positive connection to the positively activated node of his wife, so that the semi-sphere of his wife is also in contraction. Therefore, Mr. A is in an imbalanced state at this moment: he loves his wife and hates the sweater. Heider's original balance theory can simply be expressed by two semi-spheres with bidirectional connections. When the two connections are symmetric, they are reduced to one link that can be given some such label as “unit relation” (Heider, 1958). In general, a two-node semi-sphere recurrent network is in an imbalanced state if the two semi-spheres are simultaneously contracting, whereas the network is in a balanced state if the two semi-spheres are simultaneously expanding.

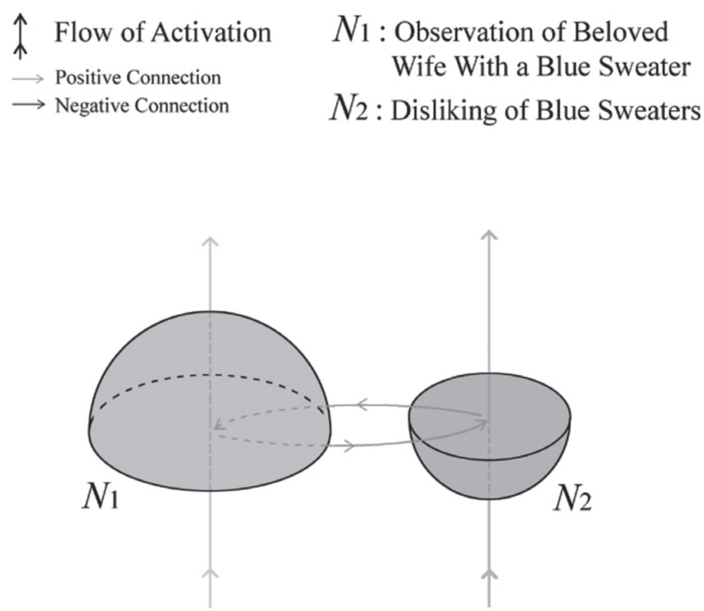

Figure 1. Two-node semi-sphere recurrent network representation of a typical imbalanced situation defined in Heider's (1946, 1958) balance theory.

Subsequent Balance Theories

Since Heider (1946), the balanced state and the relation between two cognitive elements have been given different names in the specification and extension of the balance principle. The balanced state and the relation have been labeled respectively, (a) symmetry and co-orientation (Newcomb, 1953), (b) congruity and assertion (Osgood & Tannenbaum, 1955), (c) structural balance and signed directed line with a color (Cartwright & Harary, 1956), (d) affective-cognitive consistency and instrumentality (Rosenberg, 1956, 1960), and (e) cognitive balance, and positive, negative, ambivalent or null relation (Abelson & Rosenberg, 1958; Rosenberg & Abelson, 1960).

Apart from Cartwright and Harary's (1956) structural balance theory, which pays attention to social networks rather than cognitive networks, all Heiderian balance theories can be expressed by the recurrent networks of two or more semi-spheres of positively or negatively activated nodes with bidirectional weighted connections. Each of the recurrent networks is in an imbalanced state at a particular moment if any two semi-spheres are simultaneously contracting on account of the sending and receiving activation between the cognitive elements. The speed of resolution of the imbalanced state depends upon the current input pattern, the coefficients of contraction and expansion of the semi-spheres, and the perceptual or learned connection weights in the recurrent network.

Two empirical studies (Maio & Olson, 1998; Tannenbaum, 1966) have jointly provided interesting support for cognitive dynamics in a three-node semi-sphere recurrent network shown in Figure 2. Maio and Olson showed that the increased accessibility to Einstein and the exposure to a fictitious message telling that he had made a negative assertion about nanotechnology led participants to lessen their initially favorable attitude toward nanotechnology. Assume that Einstein had made a positive assertion about evolution theory in addition to the negative assertion about nanotechnology in their experimental situation. If an independent persuasive message was given externally to increase participants' initially favorable attitude toward evolution theory, the expanded convex semi-sphere of evolution theory would have increased the positive activation of Einstein, and this expansion would in turn have led participants to lessen their initially favorable attitude toward nanotechnology more.

Tannenbaum’s (1966) findings lend support to this kind of reasoning about the flows of activation. In his study, participants were first exposed to a message in which the source’s attitudinal position on two neutral concepts (teaching machine, and Spence’s learning theory) was established. Then they were exposed to a message to change their attitude toward only the concept of teaching machine. The results showed that the attitude toward the concept of Spence’s learning

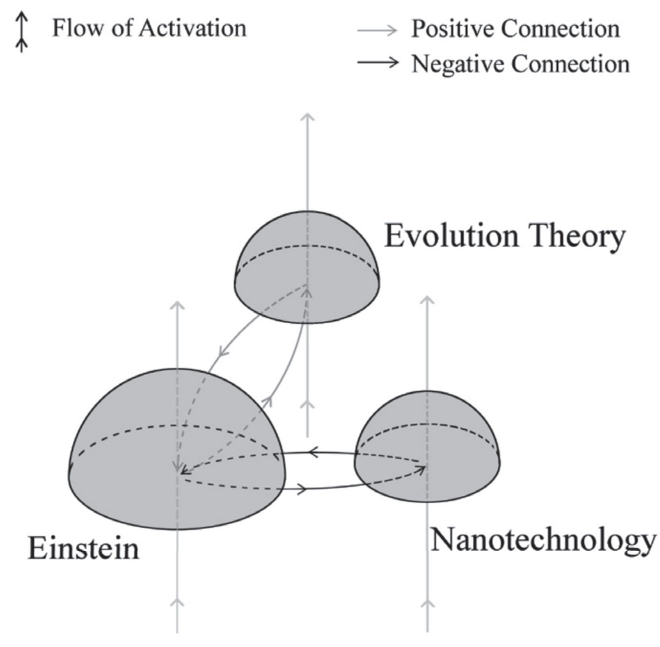

Figure 2. Three-node semi-sphere recurrent network expression of the balance/congruity principle and spreading activation in Maio and Olson’s (1998) and Tannenbaum’s (1966) experiments.

theory also changed in the direction predicted by the congruity principle. Tannenbaum (1966) called this phenomenon mediated generalization. It is quite interesting that this effect occurred without partipants being consciously aware that they were doing so (for the conception of congruity and mediated generalization, see also Tannenbaum, 1967, 1968).

Application to Dissonance Theories

Sakai (1999) has presented a multiplicative power-function (MPF) model of cognitive dissonance. In the MPF model, the term cognitive element in dissonance theory is redefined as a state of mind that can be cognitive, emotional, or motivational --- or even unconscious, although the state of mind must always be expressible in a sentence by the person in question, by the observer of this person, or by both. He has suggested that the differences and similarities between Festinger's (1957) original account and the subsequent versions of cognitive dissonance can be clarified by the identification in each version of the key cognitive element around which dissonance exists.

The key cognitive element is identified as (a) behavior-related cognition (Beauvois & Joule, 1996; Festinger, 1964; Harmon-Jones, 1999; Harmon-Jones, Amodio, & Harmon-Jones, 2009), (b) self-concept about being consistent, competent, and morally good (E. Aronson, 1968, 1992; Stone, 2012), (c) being responsible for aversive consequences (Cooper & Fazio 1984), and (d) self-integrity (E. Aronson, 1999; Steele, 1988). It is argued in the MPF model that one particular cognitive element should not be chosen as a single exclusive key cognitive element, and that any cognitive element is qualified to become a key cognitive element if dissonance theory is to be a general theory of cognitive motivation.

Dissonance Generation and Reduction

Whatever the key cognitive element might be, dissonance theory is represented by the recurrent network of two or more activated sentences, one of which is a key cognitive element, with bidirectional weighted connections. The sentence semi-sphere recurrent network is in a dissonant state at a particular moment if the key and some of the remaining sentence semi-spheres are simultaneously contracting by the flow of activation between the cognitive elements (for a mathematical formulation of the magnitude of cognitive dissonance, see Sakai, 1999). The difficulty of reduction of the dissonant state depends upon the current input pattern, the coefficients of contraction and expansion of the convex semi-spheres, and the perceptual or learned connection weights in the recurrent network.

What apparently occurs, in the reduction process of the dissonant state created by a sentence

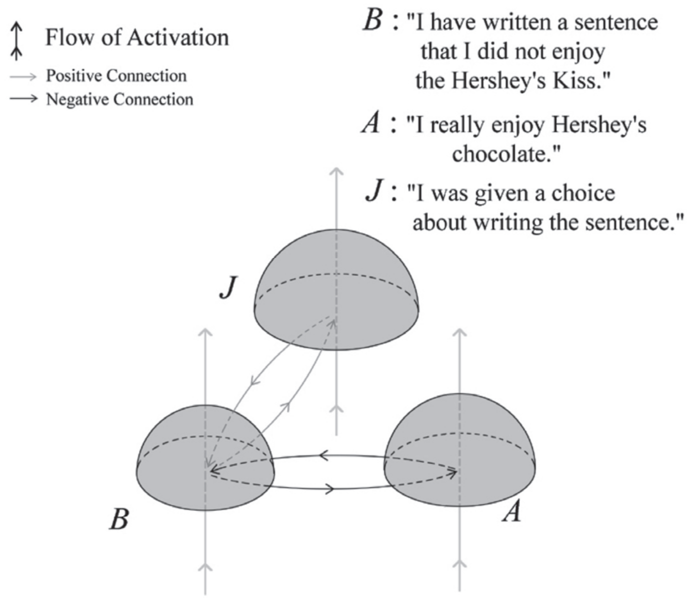

Figure 3. Three-sentence semi-sphere recurrent network expression of the original view of cognitive dissonance in Harmon-Jones's (2000) experiment.

K and a sentence *X*, is that the activation of sentence *X* changes from a positive value to a negative value in a recurrent network of sentence semi-spheres *K*, *X*, and *Y*. This is because the sentence *X* has changed into a sentence not-*X*. Therefore, it is necessary in the recurrent network model (a) to replace the negative activation of the sentence *X* (a concave semi-sphere) with the positive activation of the sentence not-*X* (a convex semi-sphere), and (b) to replace the negative connections between *K* and *X* with the positive connections between *K* and not-*X*. The difficulty of change in sign of the connections may in part depend upon the coefficients of contraction and expansion of the radially connected sentence semi-spheres.

Original View of Cognitive Dissonance

The original view of cognitive dissonance theory is expressed in Figure 3 by a sentence semi-sphere recurrent network after the experimental situation in Harmon-Jones (2000). The levels of positive activation of three cognitive elements are expressed by three concave sentence semi-spheres, *B*, *A*, and *J*. In Harmon-Jones's scheme, the key cognitive element is a very simple behavior-related cognition: *B* = "I have written a statement that the Hershey's milk chocolate Kiss did not taste good." Another is an attitudinal cognition: *A* = "I really enjoy Hershey's milk chocolate." The other is the perception of justification: *J* = "There were very few reasons to write

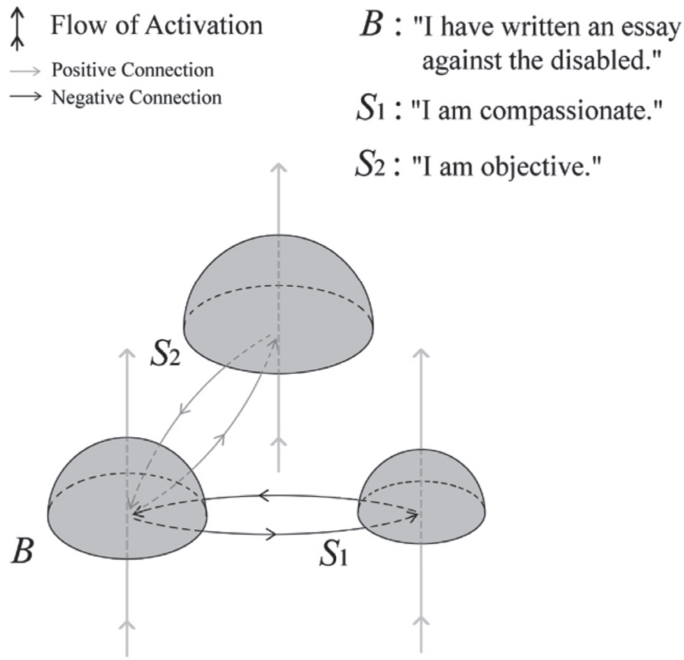

Figure 4. Three-sentence semi-sphere recurrent network expression of the self-theoretical view of cognitive dissonance in J. M. Aronson, Blanton, and Cooper's (1995) experiment.

the statement, but I was given a choice about writing it." This three-sentence semi-sphere recurrent network is in a dissonant state because two sentence semi-spheres *B* and *A* are simultaneously contracting by the flow of negative activation between them. The dissonant state was reduced by changing sentence *A* in the direction of sentence not-*A*, "I really did not enjoy the chocolate," even if no perception of aversive consequences was present.

Self-Theoretical View of Cognitive Dissonance

The self-theoretical view of cognitive dissonance is expressed in Figure 4 by a sentence semi-sphere recurrent network after the study of J. M. Aronson, Blanton, and Cooper (1995). The levels of positive activation of three cognitive elements are expressed by three convex sentence semi-spheres, *B*, S_1, and S_2. One cognitive element is a behavior-related cognition: *B* = "I have written an essay in which I argued against increased university funding to help students with physical disabilities." Another cognitive element is a self- attribute: S_1 = "I am compassionate," which can be a key element as a part of self-integrity. The other is a different self-attribute: S_2 = "I am objective." This three-sentence semi-sphere recurrent network is in a dissonant state because two semi-spheres, *B* and S_1 are simultaneously contracting due to the flow of negative activation between them.

After writing the essay, participants received feedback from a bogus personality test that they had taken earlier. It was found that they favored the feedback that informed of their high objectivity over the feedback that informed of their compassion. J. M. Aronson et al. (1995) interpreted these effects as selective self-affirmation, and called them identification and disidentification. In terms of the original dissonance theory, these effects are regarded as selective exposure to consonant information (objectivity) and dissonant information (compassion). It might be very interesting if the self could not only figure as a key cognitive element in dissonance generation (E. Aronson, 1968, 1992, 1999; Steele, 1988), but also as a target in dissonance reduction.

Cultural Differences in Cognitive Consistency

The recurrent network model of cognitive consistency facilitates to understand why some behavior might create no inconsistency among people in certain cultures, while the same behavior would create great inconsistency among people in other cultures. If a person was invited to dinner and ate pig's trotters, knowledge of which culture this person belongs to is likely to be helpful in predicting whether and how much the person experienced cognitive inconsistency (whether labeled imbalance or dissonance).

Yet, it is almost completely predictable from the information about how much the person likes or dislikes the meat. Knowledge of the volumes of convex and concave semi-spheres and the weighted connections between the semi-spheres is critical in the recurrent network model. In the process of learning under particular cultures, the culture can moderate the shape and volume of semi-spheres and the weights on inter semi-sphere connections. The recurrent network model of cognitive consistency would not need additional theoretical terms or variables other than those specified here, but might need moderating variables such as cultural differences.

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