Modeling the Role of Human Memory and Expectations in Social Exchange

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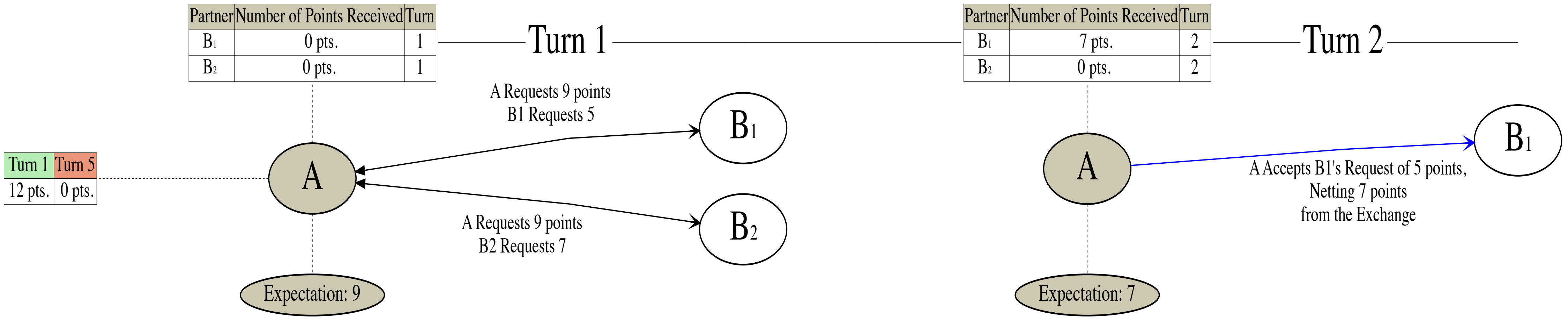

Lines Indicate Memory Retrievals & Updates

Arrow Indicate Exchanges

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Introduction

Someday –and that day may never come- I'll call you to do a service for me. But, until that day, accept this justice as a gift on my daughter's wedding day (The Godfather, 1972).

Social Exchange: The giving, collecting, trading, and withholding of favors, gifts, and resources.

Scope Conditions:

- There exists a direct or implied social relationship between two or more people.
- The mutual benefits of the relationship can only be realized through cooperation.
- The relationship's value cannot be ascertained in advance, but must be discovered through repeated exchanges.

Motivation

📖 Molm and Collett 2007; Lawler, Thye, and Yoon, 2014

Social exchange is an important source of social relations, and influences how connected we feel to those around us.

Social Exchange Theory is a framework that seeks to explain the social dynamics that govern social exchange

Learning is an important aspect of social exchange because individuals must both ***learn*** and ***apply*** different exchange logics to navigate a variety of social situations.

How individuals learn social exchange logics and apply them to new settings is, however, not well understood.

Social Exchange Theory: A Brief Overview

Theoretical Foundations: Homan’s Propositions

Homans, 1974

The Success Proposition: Behavior that generates positive consequences is likely to be repeated.

The Stimulus Proposition: Behavior that has been rewarded in the past will be performed in similar situations.

The Value Proposition: The more valuable the result of an action to an actor, the more likely that action is to be performed.

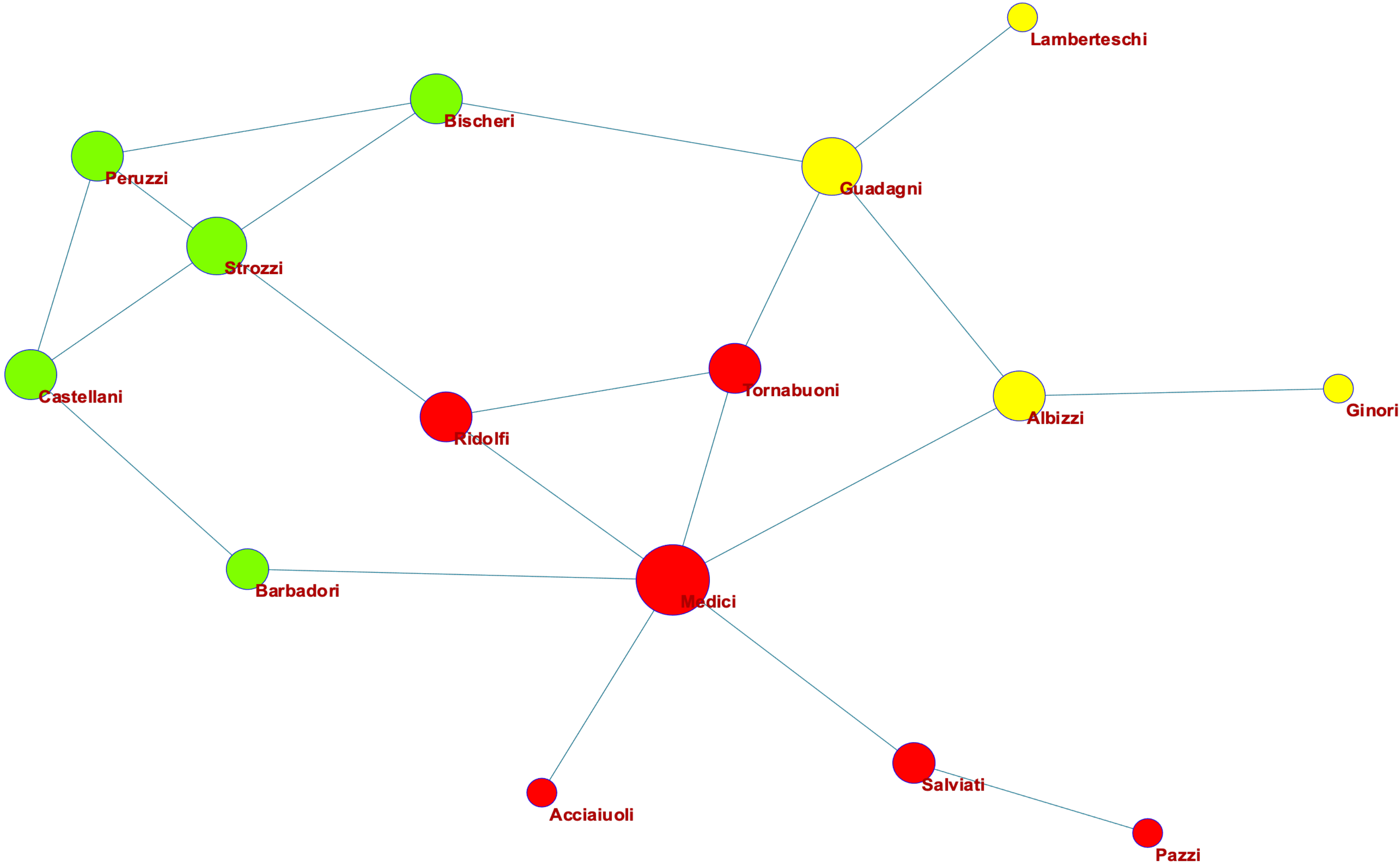
The Deprivation-Satiation Proposition: The more often a person has recently received a particular reward for an action, the less valuable is an additional unit of that reward.

The Aggression/Award Proposition: People will become angry when they do not receive what they anticipate.

Social Exchange as a Driver of Social Relations

📖 Blau, 1986

Justus Suttermans 1640

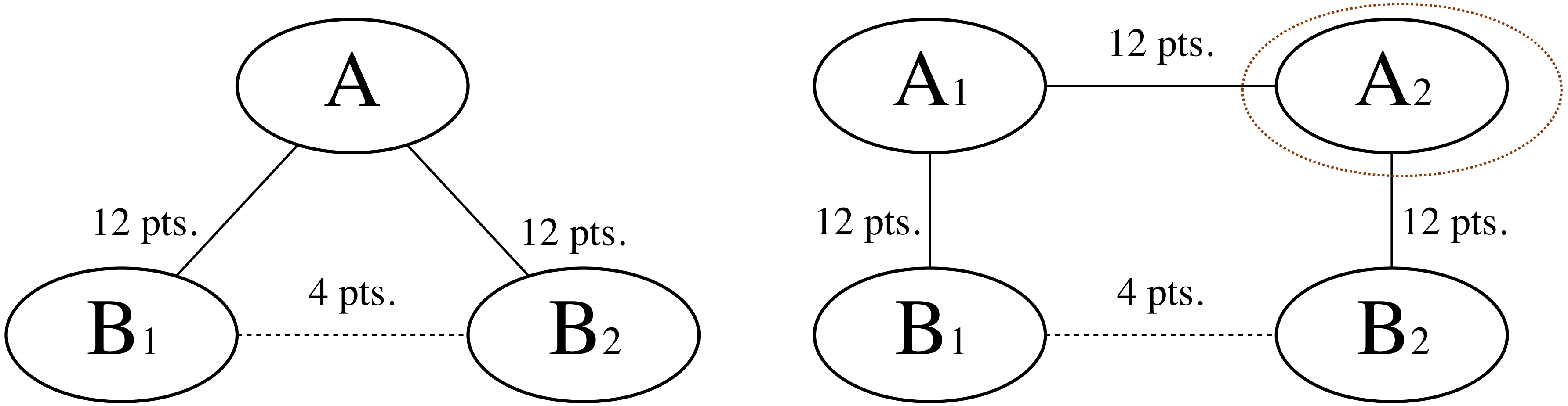


John Padgett's Florentine Families

Power is access to alternatives.

Exchange Networks: High (left) and Low (right) Relational Power

Emmerson, 1962; Emmerson 1972



High Power

Low Power

Because exchanges are mutually exclusive:

- In high power networks, only one exchange is possible.
- If A exchanges with B_1, B_2 cannot exchange with anyone.
- B positions, thus, must compete for A's cooperation.

- In low power networks, two exchanges are possible.
- For example, Bs can exchange with either an A or a B.
- The Bs, thus, are in less competition

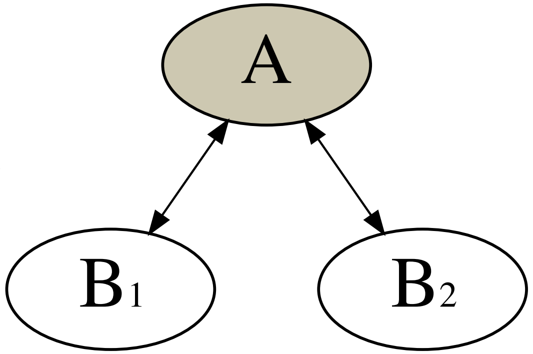
Types of Exchange

📖 Emmerson, 1972; Cook & Emmerson 1978; Molm 1997

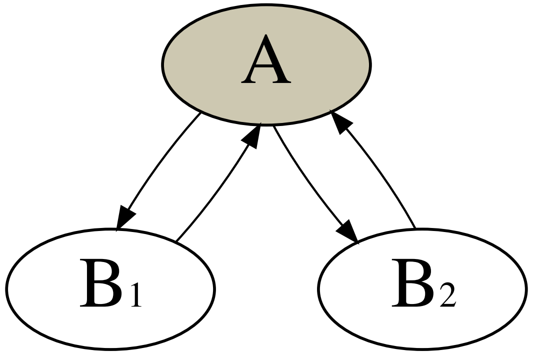
Negotiated Exchange

Reciprocated Exchange

How **A** Sees the World



Joint Action of
Self and Other



Unilateral Actions

Individuals do ***not*** know how much their cooperation is worth to their exchange partners.

They do know how much their exchange partners' cooperation is worth to them.

Exchange types differ in terms of the contingency of actor outcomes.

Experimental Design & Data

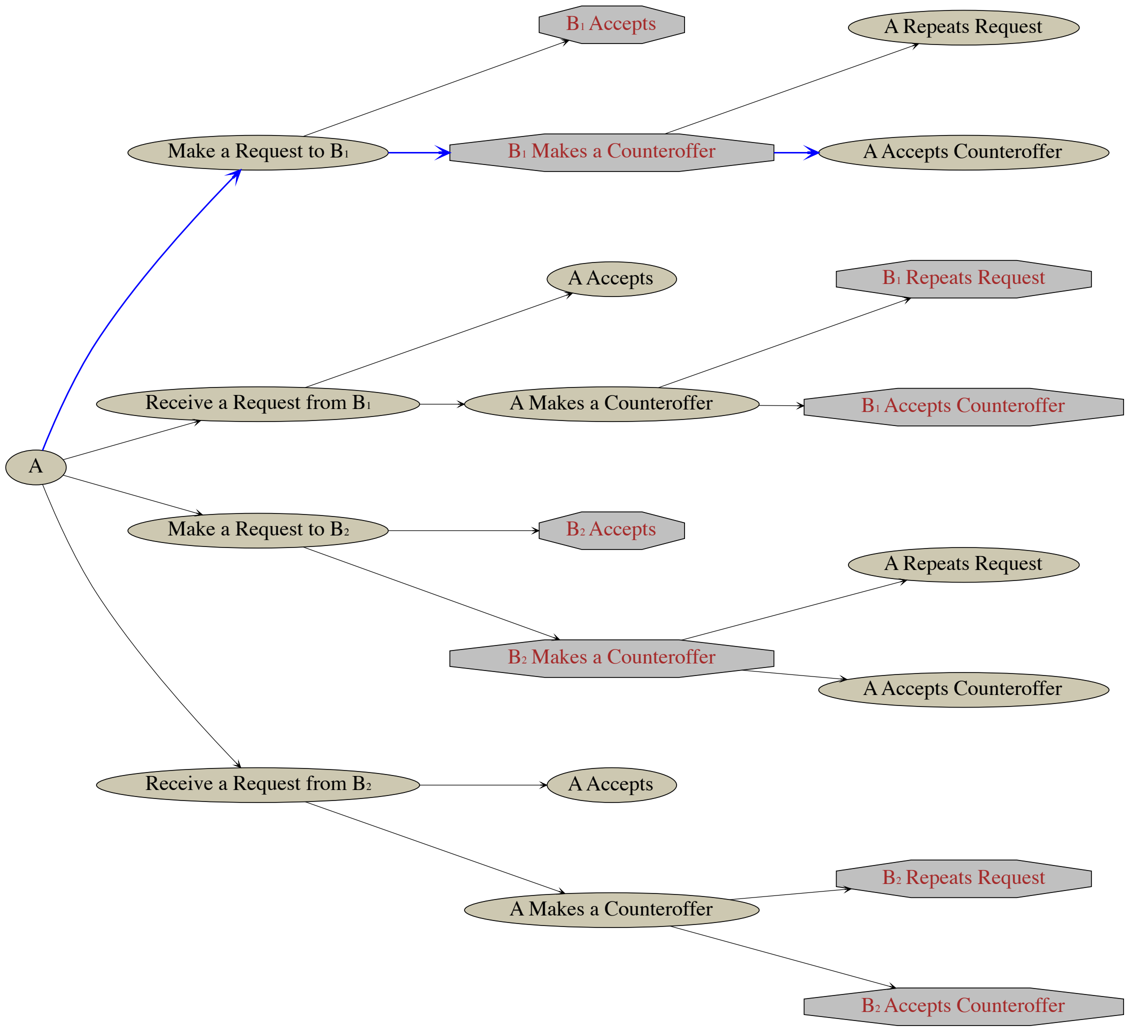
Design Summary of 2009 Negotiated and Reciprocated Exchange Experiments

	3-Person Networks	**4-Person Networks**
Negotiated Exchange	Group *n*: 48 Trial *n*: 50	Group *n*: 48 Trial *n*: 30
Reciprocated Exchange	Group *n*: 48 Trial *n*: 150	Group *n*: 48 Trial *n*: 150

Data kindly provided by David Melamed, results published in Molm et al. 2013.

Task Description: Negotiated Exchanges

Molm et al., 2013



All Potential Sequences for Two Turns of Negotiated Exchange for A

Participants make and receive requests simultaneously.

Participants can negotiate for 5 turns, if they are unable to come to agreement each receives 0 points for that round.

Participants know with whom they can exchange; they do not know their network position.

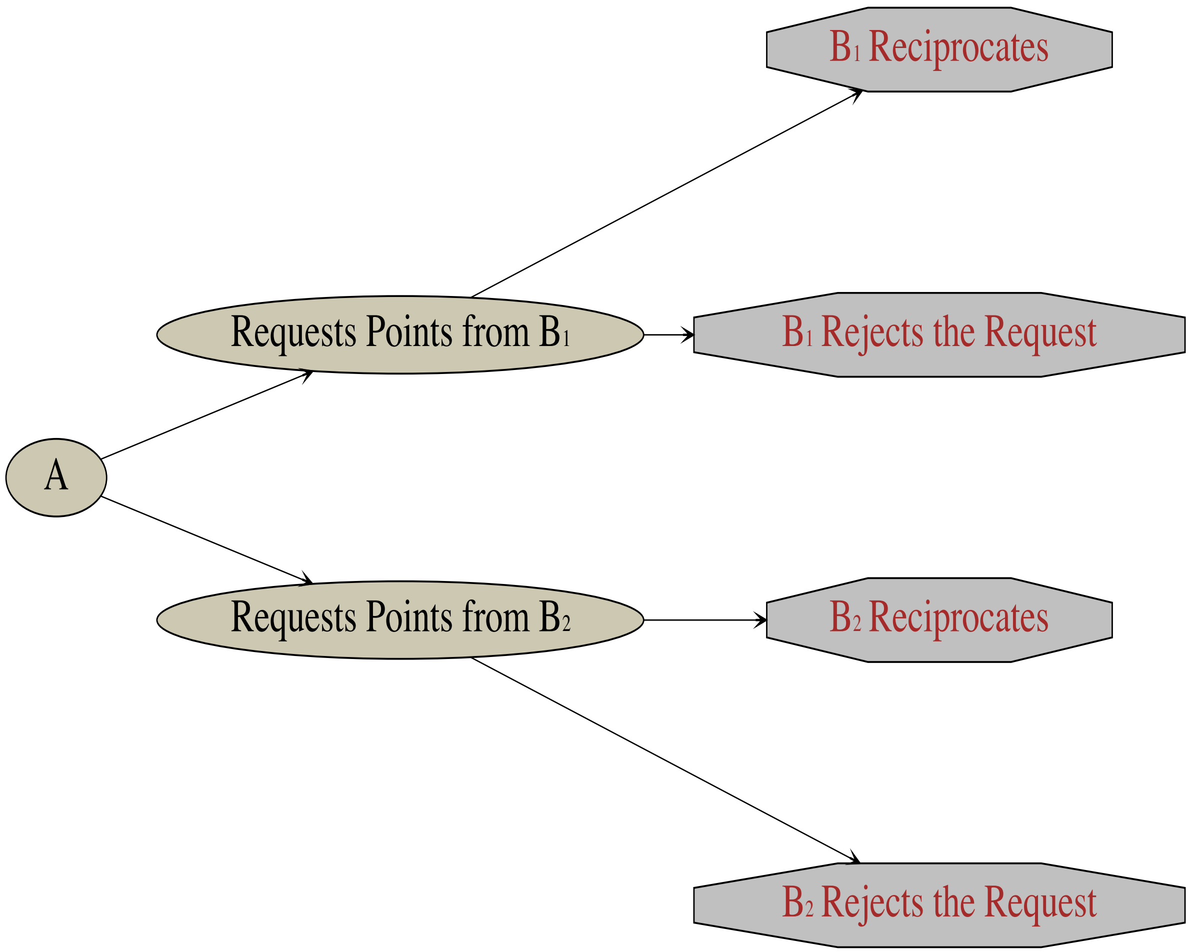
Participants know how many points they can request, and they know that more points for them means less points for their exchange partner.

Requests are converted to offers. For example, B's request of 5 points from A is presented to A as an offer of 7 points.

Participants do ***not*** know the total joint benefit or that it's fixed.

Task Description: Reciprocated Exchanges

Molm et al., 2013



Participants simultaneously and independently choose ***one*** partner they can request points from per round, without knowing whether or when their partner might reciprocate.

Giving points to a partner adds to the partner's total points without subtracting from the participant's own points.

Participants can only accept one request per turn.

Participants know with whom they can exchange; they do not know their network position.

Participants know how much they can request from a partner.

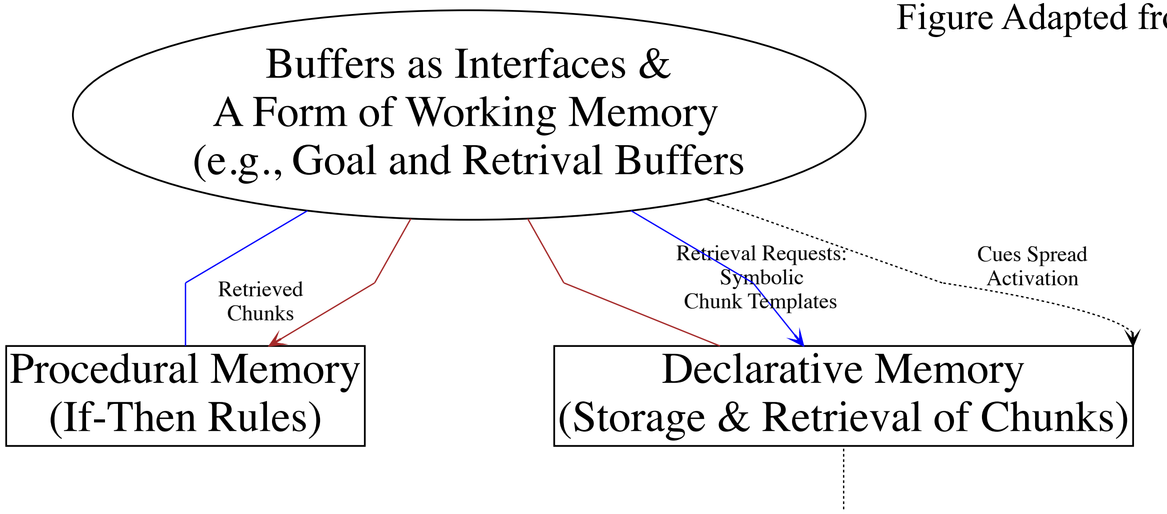
They do not know how much their cooperation is worth to their partners, or that the value is fixed.

A Cognitive Model of Social Exchange

Components of the ACT-R Architecture Relevant to the Model

Lebiere, Gonzalez, & Martin, 2007; Lebiere et. al. 2013

Figure Adapted from Reitter, Keller, and Moore, 2011



Context retrivals occur via base-level activation (recency and frequency) and spreading activation (cues).
Stochasticity is acheived via noise.
Learning based on presentation is modeled via base acitivation, and learning based on cues via spreading activation.

Our model is an agent-based model where each agent occupies either A or B position and make exchanges to earn points.

- Agents decide who to exchange with based on the knowledge they have.
- Agents learn through a progressive accumulation of decision instances.
- Instances are discrete units of knowledge (action-outcome sequences) that the agents construct, update, and reuse.

Negotiated Exchange: Model Description

Past experiences are encoded in memory as chunks (the tables in the figure) that retrieved and updated represented by the lines.

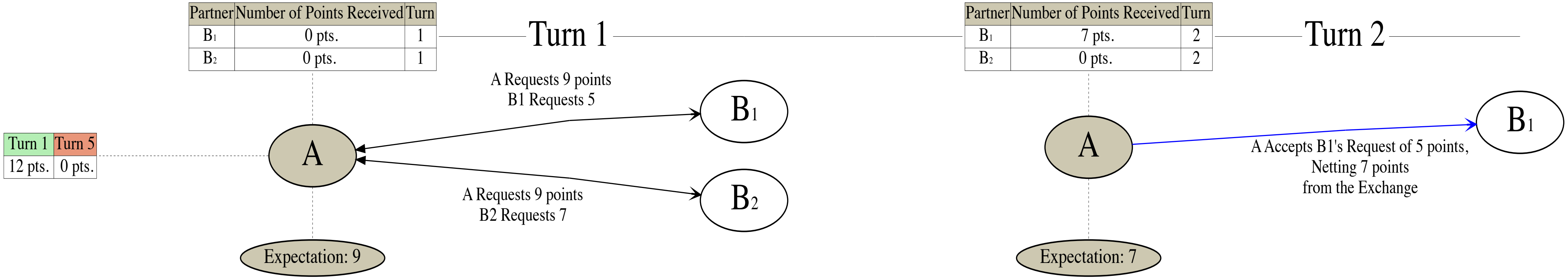
For each round, the agent generates an expectation of points that could be requested from agreements.

The expectation reflects the history of past exchanges with that partner, with the more recent ones having higher activation.

The highest offer made in the previous round is accepted if it meets the highest expectation across all partners.

Otherwise, a request is made to each partner that reflects the expectation of points from that partner at that round.

Round 1



Lines Indicate Memory Retrievals & Updates

Arrow Indicate Exchanges

Reciprocated Exchange: Model Description

The model's representation for reciprocal exchanges is very similar to the negotiated exchange model's representation.

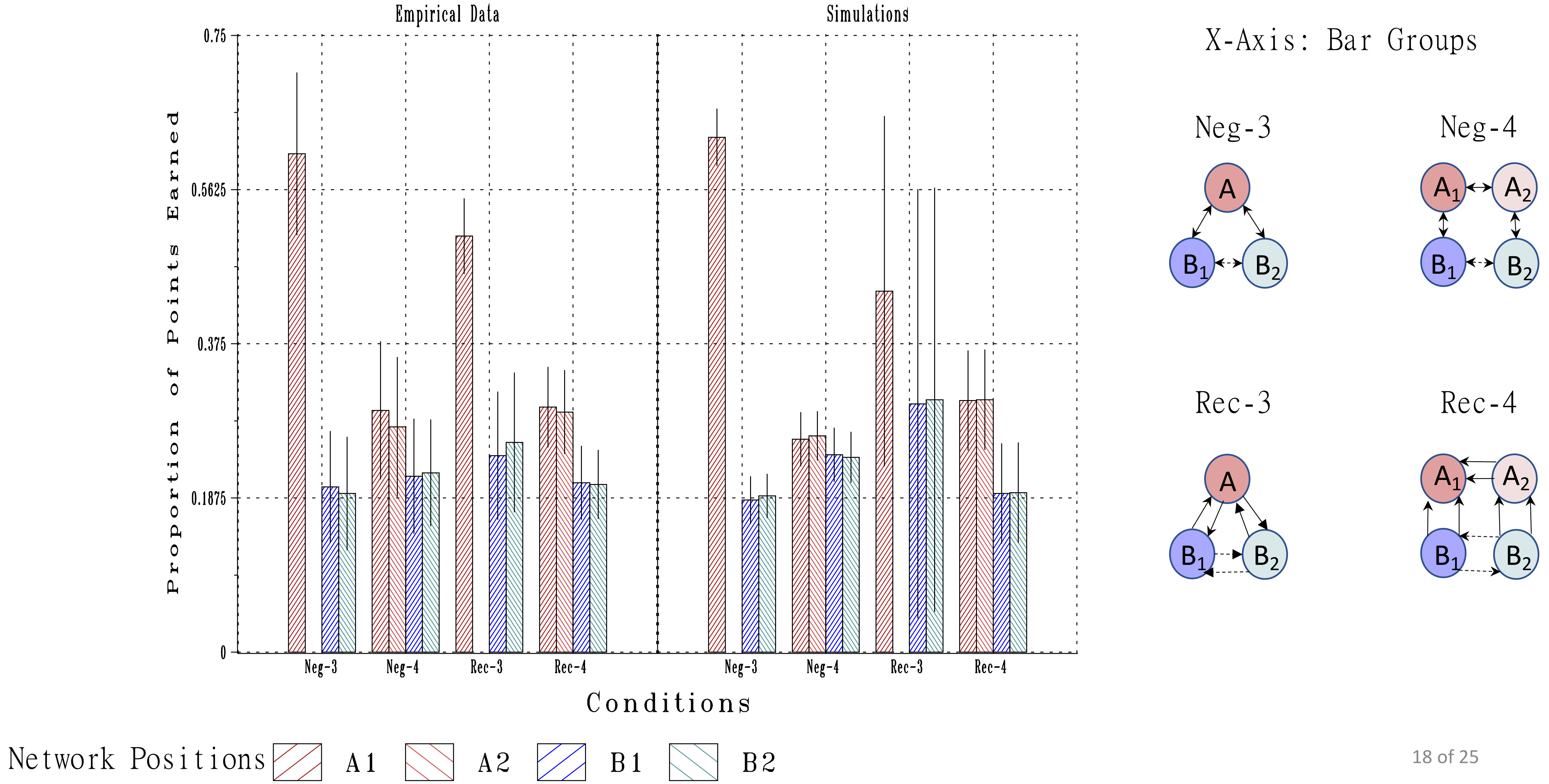
The one notable difference is because points offered are fixed rather than determined by each partner, ***the expectation generated is an estimate of the probability of receiving an offer from that partner rather than its amount***.

The model offers its points to the partner with the highest expectation

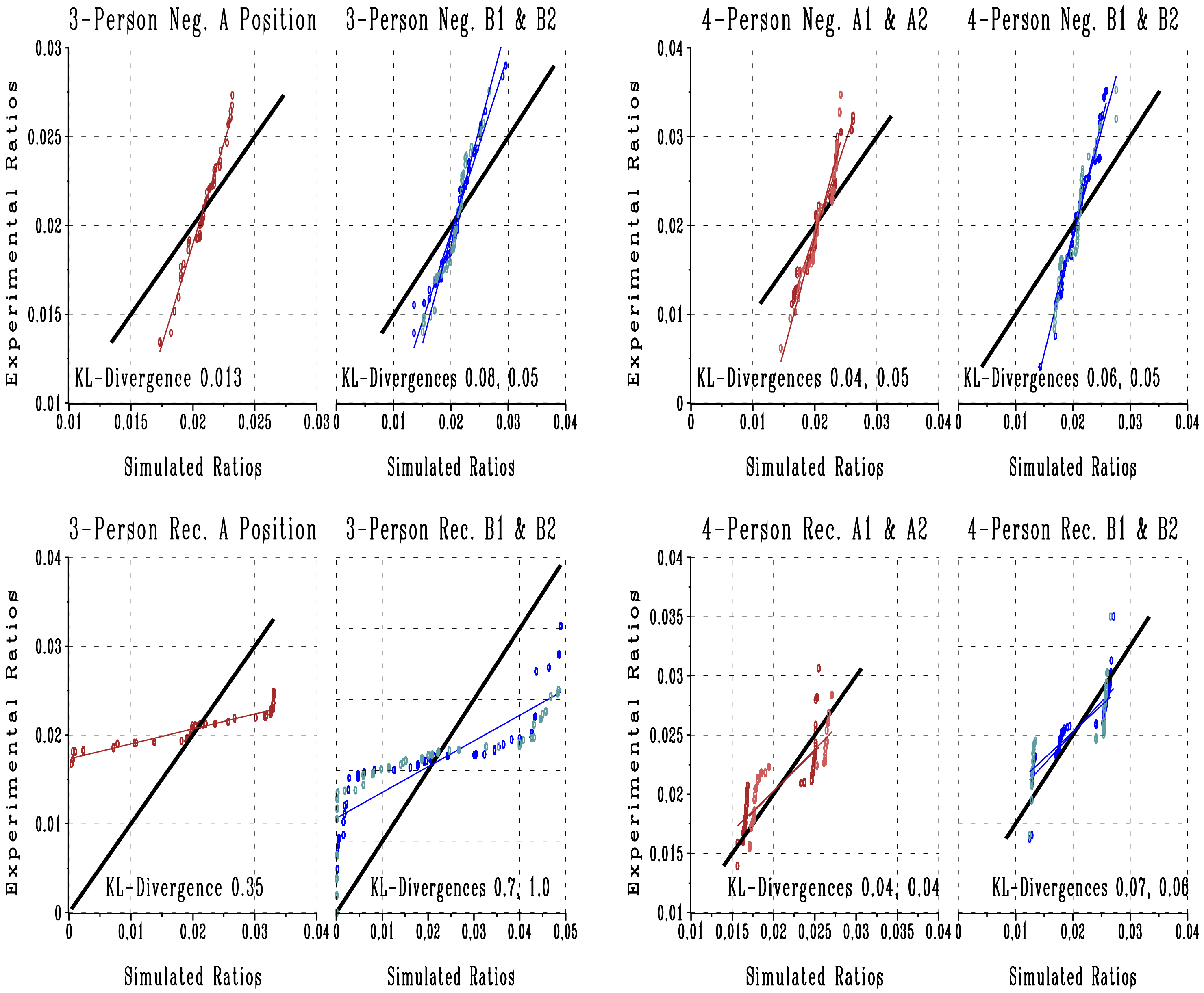
The expectation generated in the process of making the decision enters memory on the same basis as the actual outcome, leading to a form of confirmation bias where the outcome of the initial experiences get repeatedly reinforced in future trials.

Results

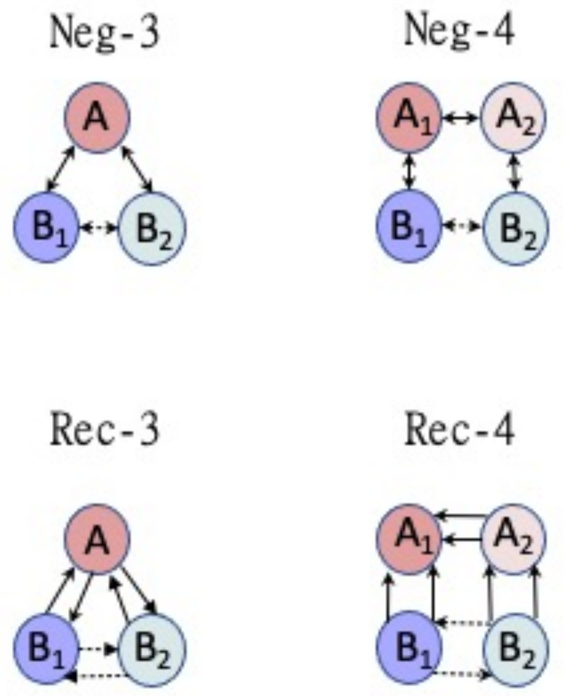
Position Ratios by Condition for Simulated and Experimental Groups



Distribution Fits by Position



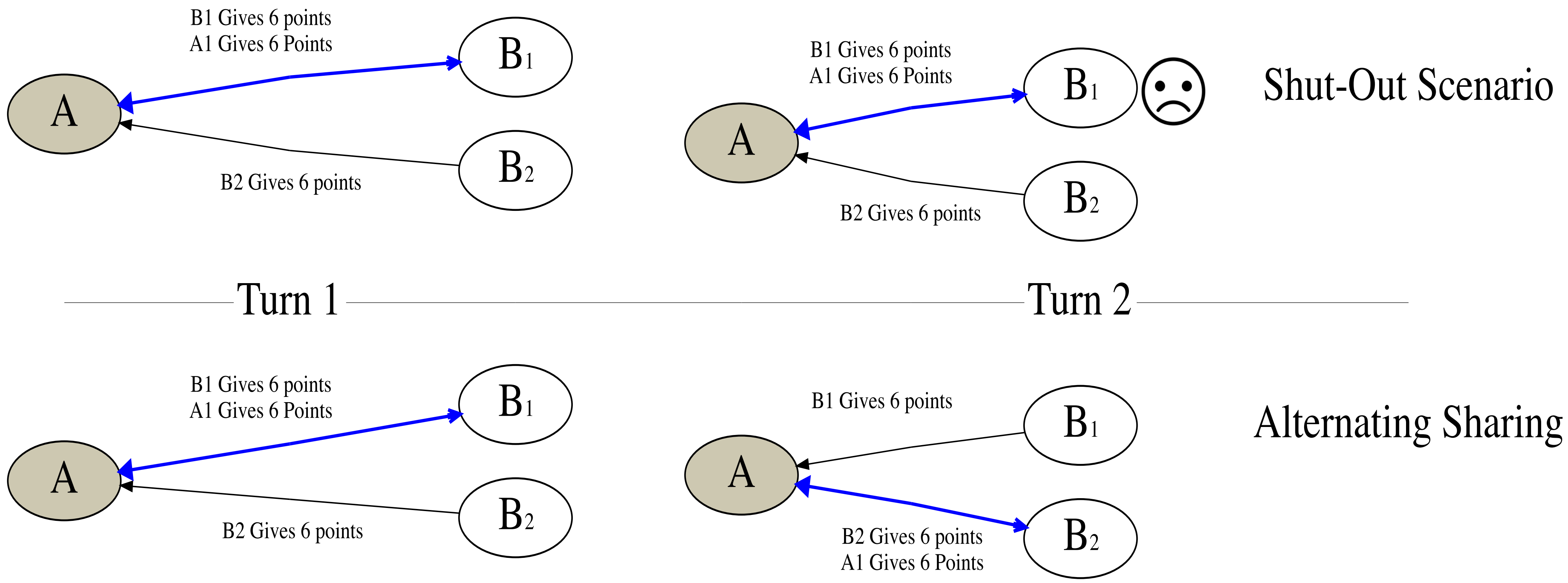
Panels indicate A and B Positions in each Exchange Network



Points indicate the ratio of points earned by actors occupying that position in a given group

Lines indicate fit.

The Importance of Early Reciprocations: Confirmation Bias & Path Dependence



Note: Because B positions receive 2 points compared to 6 if they exchange with each other, both chains are nearly equally likely. In both cases, A receives 24 points, has received points on each turn from both B positions, but B_2 has received nothing. B_2 is at risk of getting shut out in the second chain.

Point totals are adjusted to account for the difference in the number of point-earning opportunities between the two exchange types.

Conclusion and Future Directions

Conclusions

Our cognitive model of social exchange is able to replicate the distribution of points ratios for groups engaging in negotiated exchanges.

The model struggles with replicating social dynamics of reciprocal exchanges.

The model’s struggles highlight two dynamics that we are exploring now:

- ***Exploration as a Response to Uncertainty***
- ***Identity Confirmation***

Thank You

References

Blau, Peter. M. (1986). *Exchange and Power in Social Life* (2nd ed.) (ISBN 978-0887386282). New Brunswick, NJ: Transaction Books

Cook, K. S., & Emerson, R. M. (1978). Power, equity and commitment in exchange networks. *American Sociological Review, 43*(5), 721-739. doi:https://doi.org/10.2307/2094546

Emerson, R. M. (1962). Power-dependence relations. *American Sociological Review, 27*(1), 31-41. doi:https://doi.org/10.2307/2089716

Emerson, R. M. (1972). Exchange theory, part II: Exchange relations and networks. In J. Berger, Zeldtich, Jr., M., and Anderson, B. (Ed.), *Sociological theories in progress* (Vol. 2, pp. 58-87) (IBSN 0395041791 9780395041796). Boston, MA: Houghton Mifflin.

Homans, G. C. (1974). *Social Behavior: Its Elementary Forms*. (ISBN 978-0155814172). New York, NY: Harcourt, Brace, & World.

Jung J.D.A., Hoey J., Morgan J.H., Schröder T., Wolf I. (2016) Grounding Social Interaction with Affective Intelligence. In: Khoury R., Drummond C. (eds) Advances in Artificial Intelligence. Canadian AI 2016. Lecture Notes in Computer Science, vol 9673. Springer, Cham. https://doi.org/10.1007/978-3-319-34111-8_7

Lebiere, C., Gonzalez, C., & Martin, M. (2007). *Instance-based decision making model of repeated binary choice.* Paper presented at the Eighth International Conference on Cognitive Modeling, Ann Arbor, MI. Retrieved July 1, 2021, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.210.2337&rep=rep1&type=pdf

Lawler, E. J., Thye, S. R., & Yoon, J. (2014). The emergence of collective emotions in social exchange. In C. von Scheve, and M. Salmela (Ed.), *Collective emotions* (pp. 189-203): Oxford University Press Oxford. 10.1093/acprof:oso/9780199659180.001.0001

Lebiere, C., Pirolli, P., Thomson, R., Paik, J., Rutledge-Taylor, M., Staszewski, J., & Anderson, J. R. (2013). A functional model of sensemaking in a neurocognitive architecture. *Computational intelligence and neuroscience, 2013*(5). doi:https://doi.org/10.1155/2013/921695

Molm, L. D. (1997). *Coercive power in social exchange*: Cambridge University Press. https://doi.org/10.1017/CBO9780511570919

References

Molm, L. D., Peterson, G., & Takahashi, N. (1999). Power in negotiated and reciprocal exchange. *American Sociological Review, 64*(6), 876-890. doi:https://doi.org/10.2307/2657408

Molm, L. D., Collett, J. L., & Schaefer, D. R. (2007). Building solidarity through generalized exchange: A theory of reciprocity. *American journal of sociology, 113*(1), 205-242. doi:https://doi.org/10.1086/517900

Molm, L. D., Melamed, D., & Whitham, M. M. (2013). Behavioral consequences of embeddedness: Effects of the underlying forms of exchange. *Social Psychology Quarterly, 76*(1), 73-97. doi:https://doi.org/10.1177/0190272512468284

Reitter, D., Keller, F., & Moore, J. D. (2011). A computational cognitive model of syntactic priming. *Cognitive science, 35*(4), 587-637. doi: https://doi.org/10.1111/j.1551-6709.2010.01165.x

Appendix

Experimental Design: 2009 Pure Type Experiments

Three-Actor Networks

Negotiated/Reciprocated Group *n*: 12, 12 Trial *n*: 50, 150	***Reciprocated/Negotiated*** Group *n*: 12, 12 Trial *n*: 150, 50
Negotiated/Negotiated Group *n*: 12, 12 Trial *n*: 50, 50	***Reciprocated/Reciprocated*** Group *n*: 12, 12 Trial *n*: 150, 150

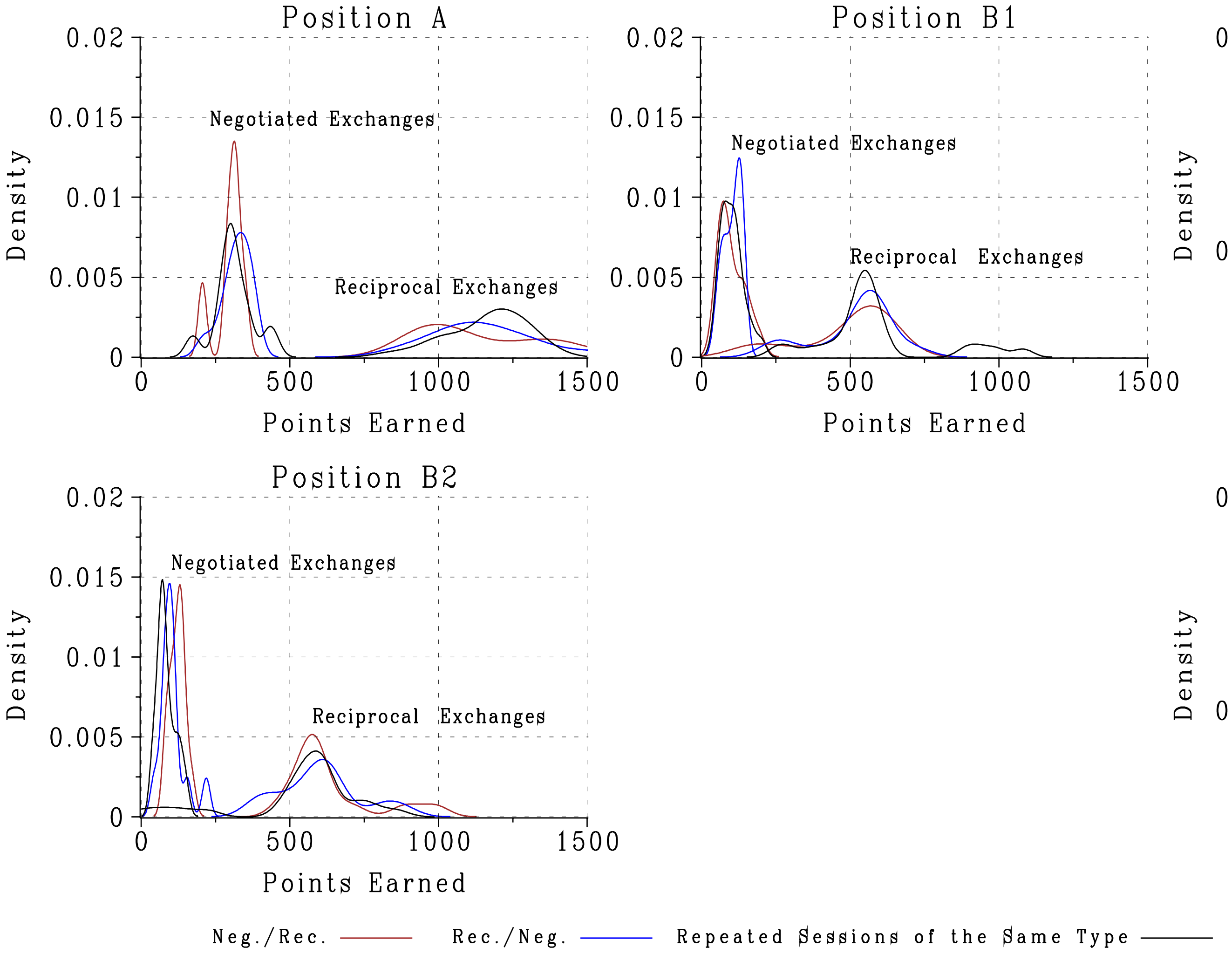
Four-Actor Networks

Negotiated/Reciprocated Group *n*: 12, 12 Trial *n*: 30, 150	***Reciprocated/Negotiated*** Group *n*: 12, 12 Trial *n*: 150, 30
Negotiated/Negotiated Group *n*: 12, 12 Trial *n*: 30, 30	***Reciprocated/Reciprocated*** Group *n*: 12, 12 Trial *n*: 150, 150

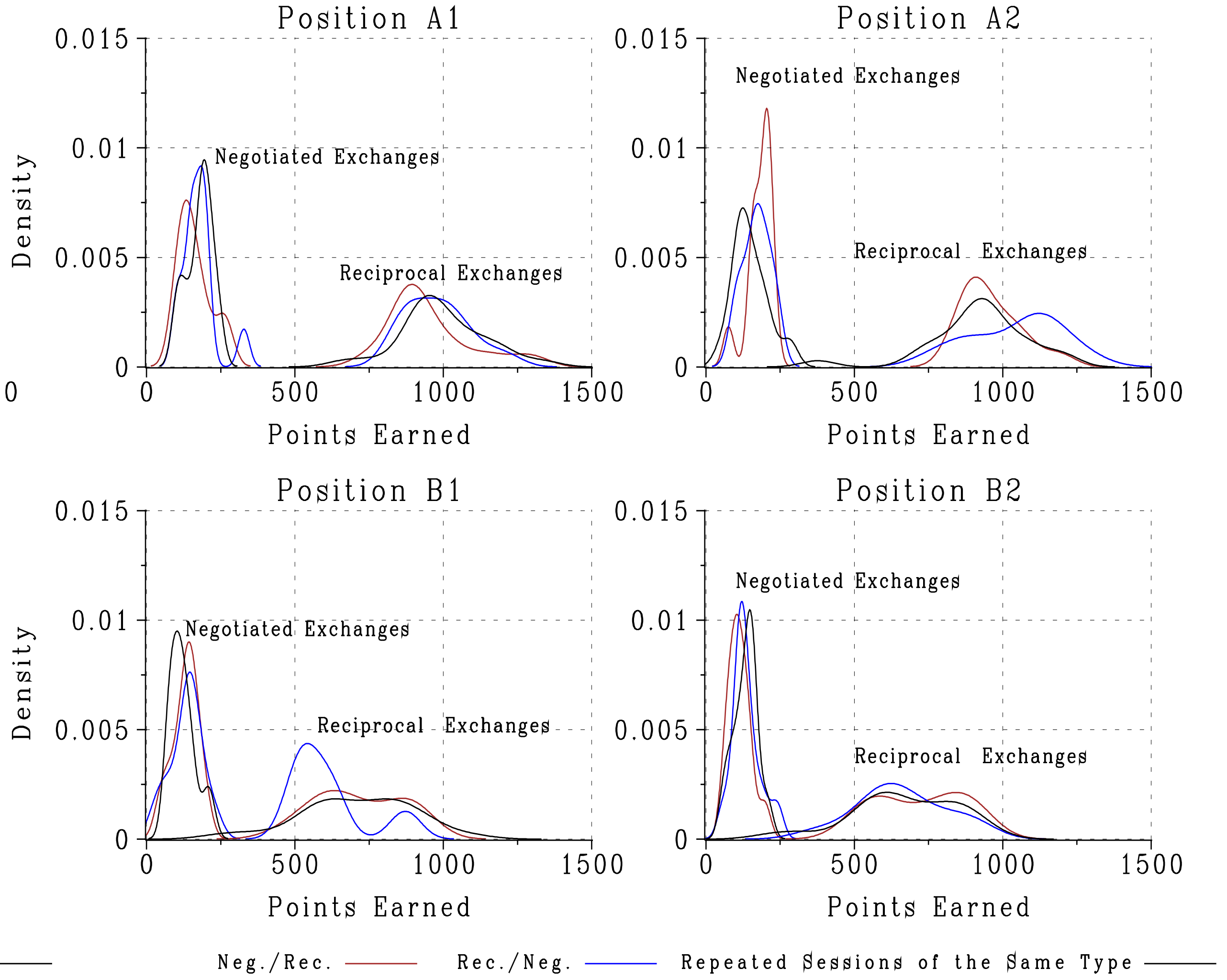
Note: Molm et al. (2013) only use results from the back-to-back blocks from these experiments as a baseline for comparing embedded/mixed exchange types collected later. Here, we are interested in all the data because our first task is to evaluate our model's performance for each exchange type before attempting to model transfer effects across types. Consequently, we want the full set of 48 observations with which to compare model results if possible.

Verifying that We Can Pool Observations

3-Person Networks



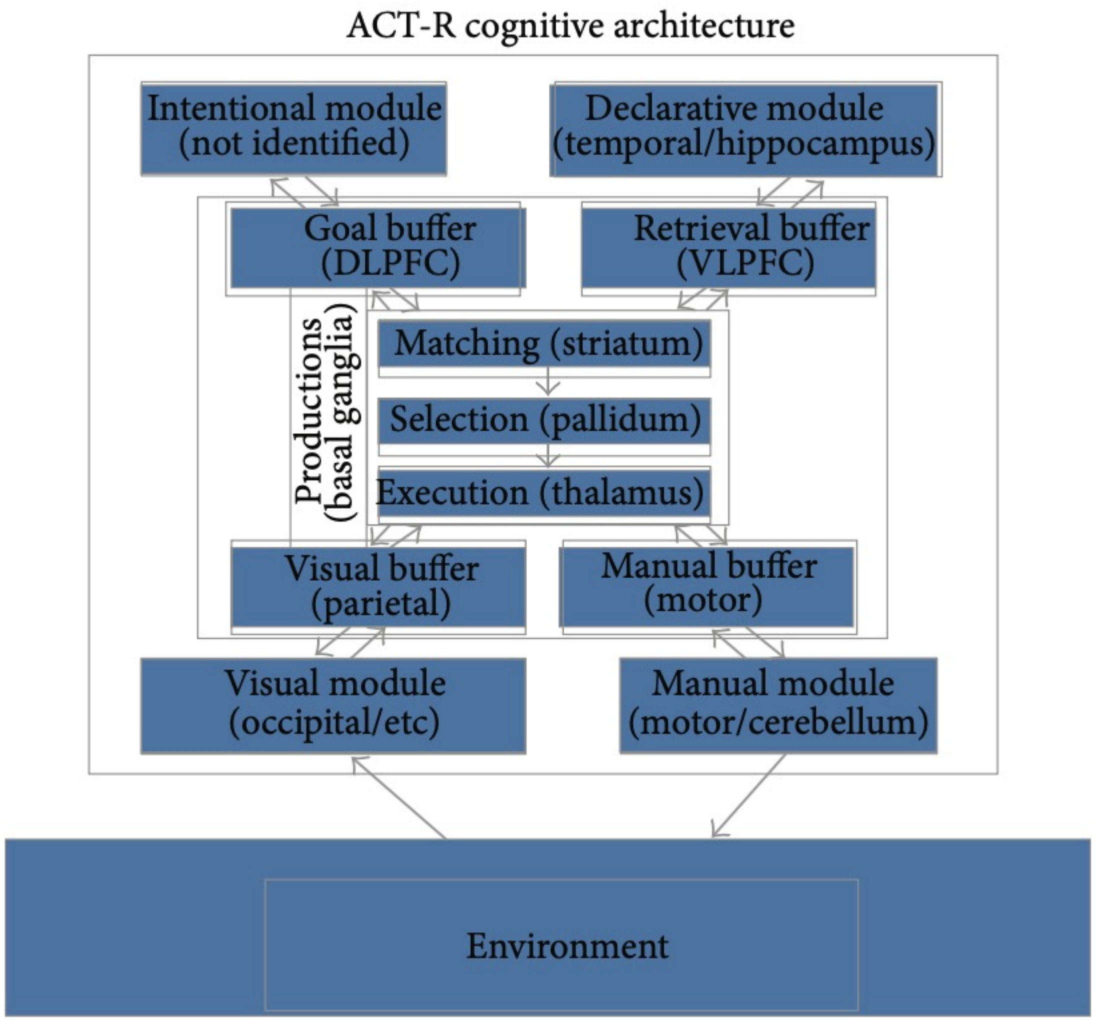
4-Person Networks



Negotiated Exchanges: 12, 12, 24 (n=48 groups) **Reciprocal Exchanges**: 12, 12, 24 (n=48 groups) per network

Summary of the ACT-R Architecture

📖 Lebiere et. al. 2013. pp. 8-9



Mechanism	Equation	Description
Activation	$A_i = B_i + S_i + P_i + \varepsilon_i$	B_i: base-level activation reflects the recency and frequency of use of chunk i S_i: spreading activation reflects the effect that buffer contents have on the retrieval process P_i: partial matching reflects the degree to which the chunk matches the request ε_i: noise value includes both a transient and (optional) permanent components (permanent component not used by the integrated model)
Base level	$B_i = \ln\left(\sum_{j=1}^{n} t_j^{-d}\right) + \beta_i$	n: the number of presentations for chunk i t_j: the time since the jth presentation d: a decay rate (not used by the integrated model) β_i: a constant offset (not used by the integrated model)
Spreading activation	$S_i = \sum_k \sum_j W_{kj} S_{ji}$, $S_{ji} = S - \ln\left(\text{fan}_{ji}\right)$	k: weight of buffers summed over are all of the buffers in the model j: weight of chunks which are in the slots of the chunk in buffer k W_{kj}: amount of activation from sources j in buffer k S_{ji}: strength of association from sources j to chunk i S: the maximum associative strength (set at 4 in the model) fan_{ji}: a measure of how many chunks are associated with chunk j
Partial matching	$P_i = \sum_k P M_{ki}$	P: match scale parameter (set at 2) which reflects the weight given to the similarity M_{ki}: similarity between the value k in the retrieval specification and the value in the corresponding slot of chunk i The default range is from 0 to −1 with 0 being the most similar and −1 being the largest difference
Declarative retrievals	$P_i = \dfrac{e^{A_i/s}}{\sum_j e^{A_j/s}}$	P_i: the probability that chunk i will be recalled A_i: activation strength of chunk i $\sum A_j$: activation strength of all of eligible chunks j s: chunk activation noise
Blended retrievals	$V = \min \sum_i P_i \left(1 - \text{Sim}_{ij}\right)^2$	P_i: probability from declarative retrieval Sim_{ij}: similarity between compromise value j and actual value i
Utility learning	$U_i(n) = U_i(n-1) + \alpha\left[R_i(n) - U_i(n-1)\right]$ $P_i = \dfrac{e^{U_i/s}}{\sum_j e^{U_j/s}}$	$U_i(n-1)$: utility of production i after its $n-1$st application $R_i(n)$: reward production received for its nth application $U_i(n)$: utility of production i after its nth application P_i: probability that production i will be selected U_i: expected utility of the production determined by the utility equation above U_j: the expected utility of the competing productions j

Future Directions: Increasing Exploration Under Conditions of Uncertainty

Molm et al.'s (2013) model of behavioral commitment predicts the chains of reinforcing behavior that we see in the model.

Nevertheless, humans not only rely on "strong ties" when confronted with uncertainty; they explore options.

In particular, individuals in the B positions are more likely to try strategies of incremental commitment.

When looking at the distribution of points across relations in the human data, the complete exclusion of either B is rare, as is the total commitment by any person to a single relationship.

Future Directions: Including Affective Information and Identity Confirmation


Given the greater resources and structural advantage of occupying an A position, A's perceptions have significant effect on the proportion of points accrued by each position.

These analyses highlight that there are multiple strategies that lead to positive outcomes for A.

Given the option of being a good group member and sharing the spoils versus being a petty one who restricts the resources to one relationship, most people share.

Rather than resorting to an ad hoc norm of sharing, we would prefer periodic sharing to emerge from the simulation dynamics.

One parsimonious approach is to implement an identity confirmation mechanism (e.g., Jung et al., 2016).

Future Directions: Isolating the Effect of Learning from the Task Structure

Our reviewers raised two important question that we are working on addressing.

First, how do you isolate the model predictions from outcomes that would arise necessarily from the task structure?

Second, how do you isolate the effect of learning?

We plan to address these questions in multiple ways:

- Compare model results to simulations where agents have no representation of the past, a Markov world, to establish a baseline.
- Train agents who learned strategies in one exchange setting, and see how they adapt to the other.
- Examine hybrid exchanges, Molm et. al.'s (2013) embedded exchanges, situations where agents must switch between exchange types during the course of the simulation. These analyses should be informative for understanding how human manages these switches.

Future Directions: Implementing Molm's Model of Behavioral Commitment

Molm, 1997; Molm, 1999; Molm, 2013