Modeling Knowledge about Possession Transfer

by

Gaylee Saliba

Submitted to the Department of Electrical Engineering and Computer Science
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Abstract

If we are to successfully create intelligent machines, it is essential to learn how to ground abstract notions, such as possession, in the physical world. In this work, I develop a model for the knowledge about possession transfer, which ties the abstract world to the physical world. The model grounds itself in spatial and time understanding, by making use of Borchardt's work on time space representations. The model identifies a list of 11 prominent possession transfer verbs and establishes a hierarchy to classify the other pertinent verbs. It also defines 6 dimensions for the possession space spanning physical possession, mental state, desire, IOU, money, and moving party. 19 TSR learning templates are developed as the representation for all the cases of all the prominent possession transfer verbs. The salient features of the verbs and their representations are identified. With these salient features, a decision-making tree is created. Near-miss learning is demonstrated to be a good learning technique for the system via 2 descriptive examples. I address the 10 questions and answers that the system can answer with my representation. In addition, 5 questions are addressed which cannot be answered. The correlation between the representation and visual events is discussed and explained with an example, proving how my representation can serve to aid a visual system in understanding the visual events it perceives in the environment.

Thesis Supervisor: Patrick Henry Winston
Title: Ford Professor of Artificial Intelligence and Computer Science

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

If we are to successfully create intelligent machines, it is essential to learn how to ground abstract notions, such as possession, in the physical world. In this work, I develop a model for the knowledge about possession transfer, which ties the abstract world to the physical world. The model grounds itself in spatial and time understanding, by making use of Borchardt's work on time space representations. The model identifies a list of 11 prominent possession transfer verbs and establishes a hierarchy to classify the other pertinent verbs. It also defines 6 dimensions for the possession space spanning physical possession, mental state, desire, IOU, money, and moving party. 19 TSR learning templates are developed as the representation for all the cases of all the prominent possession transfer verbs. The salient features of the verbs and their representations are identified. With these salient features, a decision-making tree is created. Near-miss learning is demonstrated to be a good learning technique for the system via 2 descriptive examples. I address the 10 questions and answers that the system can answer with my representation. In addition, 5 questions are addressed which cannot be answered. The correlation between the representation and visual events is discussed and explained with an example, proving how my representation can serve to aid a visual system in understanding the visual events it perceives in the environment.

1.1 Motivation

How do humans represent and learn knowledge about abstract concepts such as love, possession, time, and fear? In an effort to answer this question, it is essential to develop a system that grounds abstract notions in the physical world. An appropriate scope for this thesis is to tackle the modeling of knowledge of only one of these abstract concepts.

In alignment with the work being done in my research group – the Genesis Group, it is of great value to build a system that grounds the abstract notion of possession in the real world. Possession is fundamental to the human condition, like trajectory and transition.

My aim is to develop a system that does exactly this. Specifically, I develop a model for knowledge about possession transfer which ties the abstract world to the physical world.

To be able to call a machine "intelligent", where the standard of intelligence is set to human level intelligence, it is not enough that it can play chess, or find the shortest route from one location to another. It must be capable of performing the tasks that we humans do every day without even realizing. One of these tasks is our thorough understanding of the concept of possession. This entails our capability to learn about, for example, possession and our ability to keep track of transfers of possession amongst various agents.

1.2 Outline

This thesis is organized as follows. In Chapter 2, I briefly discuss the dependency of my work on past projects. There are 2 pieces of previous research that this thesis grounds in. The work of Borchardt is of essence to the understanding of the key representation used for the model – developed further along in the thesis. The work of Winston influences the choices made in selecting an efficient learning technique for the model – also developed further along in the thesis.

In Chapter 3, I go through an overview of how I plan to construct my model. I breakdown the tasks and go through the steps involved in the construction to arrive at the final version of the model.

In Chapter 4, I design the architecture of the system and the implementation of the developed representation. I begin by identifying the verbs which need to be analyzed. I continue by pointing out the fundamental ideas and specifications I desire the system to have in terms of the possession space and its dimensions. I then describe the knowledge representation I use and the underlying assumptions this representation implies. Finally, I implement this representation by creating all the templates for each of the verbs under study.

In Chapter 5, I discuss the learning of the representation. I begin by identifying the salient ideas, which emerge from the knowledge representation templates. I use these to develop a decision-making tree. I go on to show how near-miss learning is the preferred technique to learn these representation templates. I address 10 questions that the system can and 5 questions that the system cannot answer. I finally discuss and illustrate how the representation is correlated to visual events.

In Chapter 6, I discuss various options for future work improvements and extensions to this work to render it more comprehensive and accurate.

In Chapter 7, I outline the contributions I made toward creating intelligent artificial systems.

Chapter 2

Background

2.1 Dependency on Other Projects – Past Work

My model relies heavily on prior work done by Gary Borchardt. It also incorporates the ideas of the work done by Patrick Winston. I describe possession transfer sequences using Borchardt's work in A.I. on transition space representations. I also suggest that a good way to learn these representations is using Winston's work on near-miss learning.

2.2 Gary Borchardt's Transition Space Representation Templates

Borchardt believes in the idea that time is perceived not as a continuum but as a sequence of discrete moments. That is, the delineation of events relies on qualitative changes in state and not on absolute time measurements.

In his work "Causal Reconstruction", Borchardt tackled the task of how to read a written causal description of a physical behavior, form an internal model of the described activity, and demonstrate understanding via question answering. His work characterizes the causal reconstruction issue and introduces the transition space representation. His representation depicts events in terms of collections of qualitative state changes, namely transitions. He applies this representation to perform causal reconstruction on physical activities described in English by implementing the PATHFINDER program. The main feature of

PATHFINDER is its ability to form causal chains by identifying and using partial matches between the various event representations.

In the Bridge project, Borchardt's conceived representation is used to describe state changes in terms of a vocabulary of qualitative changes called transitions.

Although Borchardt's work was done in the spirit of physical events, I will be extending his model to tie it in with the abstract and mental notions related to possession – thus, fulfilling the aim to provide a system that grounds abstraction in the physical world.

The transition state representation, TSR, template is a matrix that describes an event in terms of the qualitative state changes of the attributes pertaining to that event over time. An example of what a template may look like is shown below.

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∄	∄
Mental A	∄	↑	∄	∄
Desire A	A	∅	∅	∅
IOU A	∄	∄	∄	∄
Money	∄	↓	∄	∄
Poss. B	∄	∄	A	∅
Mental B	∄	∄	↑	∄
Desire B	A	∅	∅	∅
IOU B	∄	∄	∄	∄
Money	∄	∄	↑	∄

Figure 2-1. Sample transition state representation template.

The columns are the time points, which are delineated not by absolute time but by qualitative changes of state. The rows are the

various attributes of the representation. To read such templates, we must understand and be clear on Borchardt's 10 state change characterizations. These are the ways we perceive the attributes, the dimensions of the space, changing over time. The full set of 10 state change possibilities are taken from Borchardt's work in "Causal Reconstruction" and shown below. These characterizations are self-explanatory and I will not go into any discussion about their meaning.

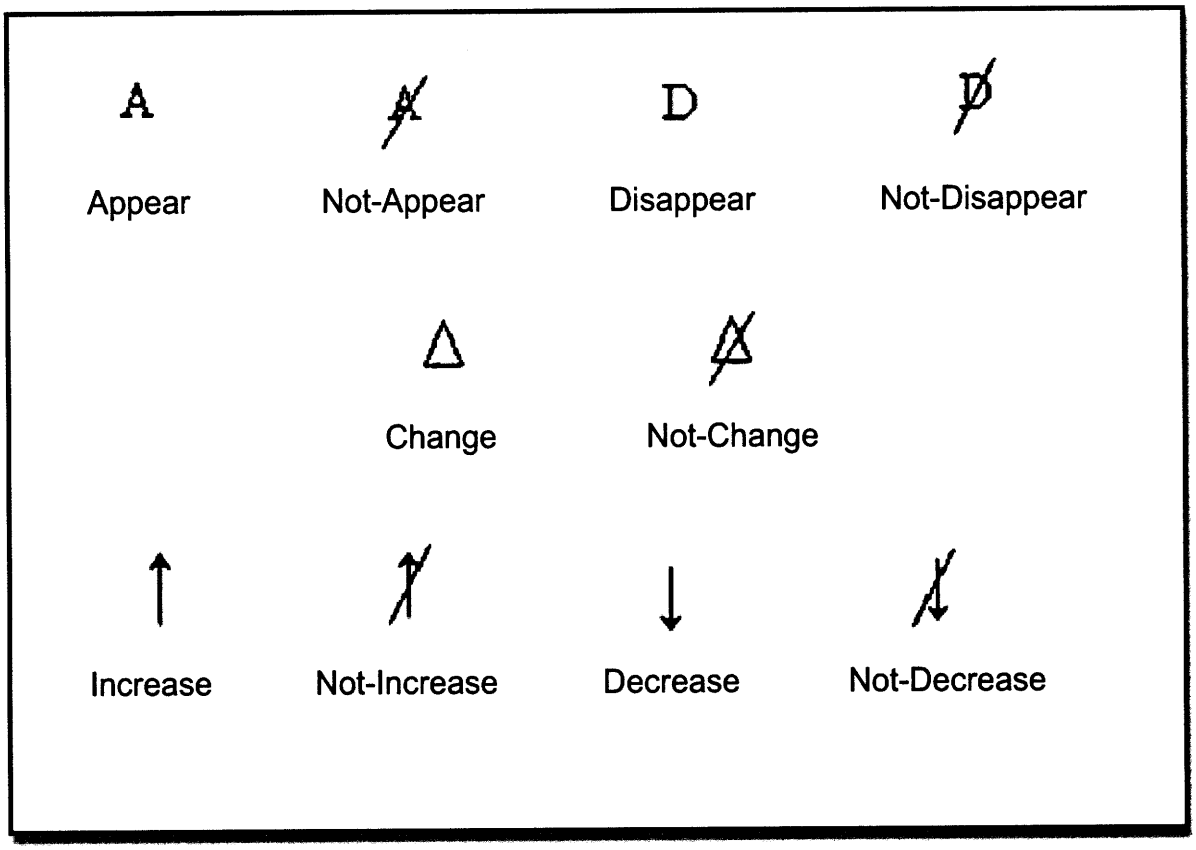

Figure 2-2. Ten state change characterizations.

2.3 Patrick Winston's Near-Miss Learning

Winston believes that we learn best by examples, specifically by negative examples or "near-miss" examples. He supports the idea that the ideal way to train a system to learn to recognize descriptions is by the human supply of examples that are all near-misses, provided with an

initial positive example of the description. Carefully chosen near-miss examples make way for a system to realize what are the salient qualities to learn in a concept as well as which features are never found in that concept.

In his work "Learning Structural Descriptions from Examples", Winston created a model for learning structural descriptions from examples. His research focused on how machines identify concepts and learn concepts to be identified. He developed a program which took in sample scene inputs to create models of simple toy-block configurations. The contributions of his work demonstrated the importance of using good descriptions to explore how machines can learn to perceive and understand the visual environment as humans do.

The model begins with a description of the example of the concept to be learned. The positive example description is the initial model. The following input examples will be either positive or, ideally, near-miss ones. The presentation of these inputs to the system lead to iterations of the model, updated each time with the new information it has learned – typically it will slightly increase the specification of the model.

There are 6 near-miss heuristics: require-link, forbid-link, climb-tree, enlarge-set, drop-link, and close-interval. Require-link is applied when an evolving model has a link in place where a near-miss does not. Forbid-link is applied when a near-miss has a link in place where an evolving model does not. Climb-tree is applied when an object in an evolving model corresponds to a different object in an example. Enlarge-set is applied when an object in an evolving model corresponds to a different object in an example but these 2 objects are not related via a classification tree. Drop-link is applied when objects that are different in an evolving model and in an example form a complete set, as well as when an evolving model has a link that is not in the example. Close-interval is applied when a number or interval in an evolving model corresponds to a number in an example. The result will be an interval

that spans from the evolving model's number or range to the example's number.

Let me go over a simplistic example. Say you want to teach an alien about ostriches. You begin by showing it an ostrich with the following characteristics: tall, long neck, long legs, and black feathers. You then pick negative examples to emphasize what qualities it has and does not have. Some of these examples could be a giraffe, a penguin, a crane, and a kangaroo. A giraffe is: very tall, long neck, long legs, and brown fur. A penguin is: short, short neck, short legs, black feathers, and can't fly. A crane is: tall, long neck, long legs, black feathers, and can fly. A kangaroo is: tall, short neck, long legs, and brown fur.

To teach the system the notion that ostriches cannot fly, the best example to present to the initial model is the near-miss "crane" as it is the only other animal that can fly while having all other features identical to the ostrich. This negative example narrows in exactly on what the ostrich is not. The initial model of the ostrich does not have the link to "fly" whereas it exists in the near-miss example of the crane – forbid-link heuristic.

Chapter 3

Construction of the Model

3.1 Task Breakdown

There are two questions we must ask ourselves to solve the problem at hand:

1 – How is the notion of possession transfer learned?

2 – Once knowledge of possession transfer is present, how does one keep track of various sequences of possession transfer?

3 – What are the salient features of the model?

4 – With a model in place, what can a system understand from a representation?

5 – How is the representation correlated to visual events and is it of value by serving as an aid to a visual system to understand the events observed?

The answers to these 5 questions are the 5 main steps in the approach to building my model.

I work on steps 1 and 2 in the reverse order. First, developing a robust representation for possession transfer sequences; then, going one step back to develop a learning algorithm for the acquisition of knowledge about possession transfer. It is most efficient to do so because it is easiest to determine the optimal learning algorithm once it is understood, through the representation for possession transfer sequences, what we would like to replicate.

My specific design process consists of several steps. In the diagram below on the following page, I have drawn them out:

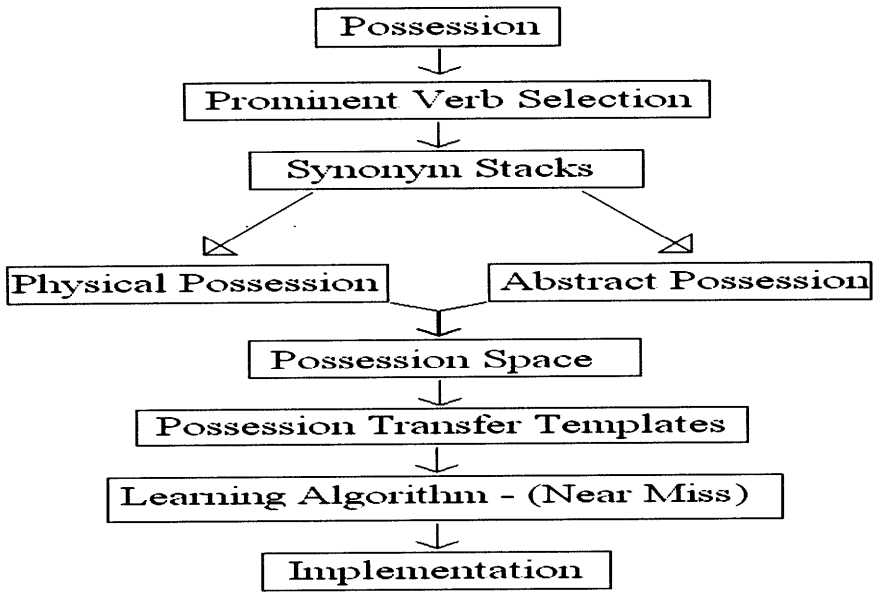

Figure 3-1. Overall architecture for design process of the model.

3.2 Quick Overview of the Model

I begin by explaining the terms possession and transfer of possession in the context of my work. Once these terms are well defined, I select – and place into a list – the prominent verbs pertaining to possession by looking at all the actions related to possession. Following the formation of the list, the other verbs, which are subsets, get classified into a hierarchy under the prominent verbs. At this point in the process, I split the work into two components – the development of the model for physical possession and that of the one for abstract possession. As I explain in its definition, possession needs to be divided into two main types: physical possession, e.g.: "I gave you a car", and abstract possession, e.g.: "I gave you a cold" or "I gave you an idea" – where nothing concrete or physical is actually being transferred but there is an instance of possession transfer on the abstract and mental level. For each kind of possession, the steps to arrive to the "possession space" in Figure 1 are done. The results are then aggregated into 1 "possession

space". I begin by considering physical possession. First things first, I define what I call "possession space". After defining all of the possible transfers – from the prominent possession transfer verb list – in possession space, each one gets a representation known as a transition space representation "TSR" template. Once the space is defined, the verbs are properly categorized, and all templates are built, I go one step back and develop the learning algorithm. I discuss the different ways the representation is of value. First, by identifying its salient features of the verbs. Second, by going over the most suitable learning algorithm tools. Third, by correlating the representation to the vision world and describing how it can be of use in helping vision systems.

3.3 Architecture of the Model

There are several steps that were performed to realize the final model. In this section, I go through each of those to reach the final architecture of the system.

3.3.1 What is Possession?

Before I can come up with a model of how knowledge about possession is acquired, it is essential to understand exactly what is defined as possession. Thus, I take the time to ask the question: What is possession?

To provide the most applicable definition in the context of the model being built, I have found the following three definitions helpful:

> *The act, fact, or condition of having control of something.*[1]

> *Possession is having some degree of control over something else. Generally, to possess something, a*

[1] Merriam-Webster's Dictionary of Law, © 1996 Merriam-Webster, Inc.

person must have an intention to possess it. A person may be in possession of some property (although possession does not always imply ownership).[2]

[Law] *Actual holding or occupancy with or without rightful ownership.*[3]

The first definition is short and general. It is the main point to remember about possession. The second and third definitions, in addition to being reiterations of the first definition, bring up important aspects of possession we need to remember.

The second definition mentions that, in order to possess something, there is generally an intention to possess. Indeed, there are cases where there is no intention – what I call no "desire" – to possess something. A good example of such a scenario is demonstrated in the following sentence:

Bill gave Jane a cold.

Obviously, Jane has no desire to "possess" a cold but yet does. The second definition also makes note (in parentheses) that possession does not always imply ownership. This is important as we realize that it is possible to possess something for a temporary period of time without it being ours (forever). A good example of such a scenario is demonstrated in the following sentence:

Bill lent Jane his car.

Jane does not own the car. However, the car is in her possession for a certain period of time – until she returns it to Bill.

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[2] http://en.wikipedia.org/wiki/Possession Wikipedia, the free encyclopedia © 2001-2005 Wikimedia Foundation Inc.

[3] The American Heritage® Dictionary of the English Language, Fourth Edition Copyright © 2000 by Houghton Mifflin Company.Published by Houghton Mifflin Company. All rights reserved.

The third definition, written in the field of law, raises the issue of rightfully versus unrightfully owning – consequently, possessing – something. The condition of unrightfully possessing something falls under what is known to us as theft (of any kind). A good example of such a scenario is demonstrated in the following sentence:

Bill stole the car.

Here, Bill unrightfully has possession of the car being that he stole it.

Finally, to render our definition of possession complete, I add one more important point. One can possess something concrete and physically tangible (e.g. a car) or something abstract and physically intangible (e.g. a cold).

It is this last point that splits the development of my model into two sub-models, which will be aggregated together to form the final complete model. One sub-model represents the case of what I denote as physical possession and the other the case of what I denote as abstract possession.

3.3.2 What is a Transfer of Possession?

Now that I've provided for a definition of possession, I must finish by defining in simple terms what I call a transfer of possession. A transfer of possession is merely the movement in space – physical or abstract depending on whether we are dealing with physical possession or abstract possession – of a possession from one party to another. It may be a temporary transfer or a permanent one, and a desired transfer or an undesired one. Finally, the transfer interaction may occur between two or more parties. An example of such a scenario would be that we are given 3 parties, A, B, and C. A transfer then occurs from A to B followed by a transfer from B to C, and so forth. A simplistic way to handle this is to break down the various transfers by sequential order into successive transfers of possession between solely 2 parties. From this point on, we

will only be dealing with transfers of possession between 2 parties – denoted A and B.

3.3.3 List of Prominent Transfer of Possession Verbs

The next requirement is to formulate an inclusive list of prominent transfer of possession verbs pertaining to possession transfers.

Using 4 online resources providing 600 of the more common regular verbs[4], the 125 most common verbs[5], the 600 most commonly used English words[6], and a list of 211 irregular verbs[7], I extracted all 29 possession transfer verbs found:

> accept, borrow, bring, buy, carry, deliver, divide, drop, fetch, find, get, give, hand, lend, lose, obtain, offer, provide, received, rob, return, sell, share, snatch, steal, supply, suspend, take, trade.

I also gathered an additional set of 10 transfer possession verbs from the EAGLES (Expert Advisory Group on Language Engineering Standards) project[8]:

> abandon, acquire, allocate, barter, donate, distribute, exchange, lease, procure, seize.

I selected this set from their provided sample based on the need for additional representations to create a larger analysis.

As a result of the extraction of data from these resources, I have gathered a sum of 39 verbs to consider.

For the purposes of this work, any transfer of possession to an unknown recipient is not considered. That is, I am building representations for possession transfers occurring between, from, and to

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[4] http://www.englishclub.com/vocabulary/regular-verbs-list.htm
[5] http://www.english-for-students.com/Frequently-Used-Words.html
[6] http://www.myenglishlessons.net/most_common.htm
http://www.myenglishlessons.net/next_two_hundred.htm
http://www.myenglishlessons.net/next_three_hundred.htm
[7] http://www.usingenglish.com/reference/irregular-verbs/
[8] http://www.ilc.cnr.it/EAGLES96/rep2/node10.html

explicit parties – whether these parties depict people or places. This removes from our consideration the following verbs:

abandon, acquire, find, get, lose, obtain, procure, receive

These verbs can only specify a recipient or donor of the possession with additional context.

Bill (A) lost his car.

With the addition of context, we could have:

Bill (A) lost his car to Jane (B).

This second addition would allow for a proper representation but I hold back from assessing these special verbs. This considerations bring me to a total sum of 31 verbs to consider.

My second step was to identify the verbs of interest by creating a hierarchy to classify the prominent transfer of possession verbs in the top-level and the special cases of these fall in the lower-level subsets below them. I selected the set of prominent transfer of possession verbs based on usefulness, frequency of usage, and most inclusive meaning. I selected subjectively based on my sense of usefulness. The other verbs are subordinate to the prominent ones by being semantic synonyms with minor differences.

1. **ACCEPT:** a subset of "take", where an emphasis is placed on agreeing to take the possession.
2. **ALLOCATE:** a subset of "give". Giving does not imply a specific allocation between 1 or more parties, but allocating necessarily implies giving.
3. **BARTER:** a subset of "exchange". Bartering involves exchanging two different types of non-monetary goods.
4. **BORROW:** prominent verb.
5. **BRING:** a subset of "give", this verb only implies a transfer of possession with added context. "Jane brings a cake, which Bill takes." This is not a stand-alone possession transfer verb.

6. **BUY:** prominent verb.
7. **CARRY OVER:** a subset of "give", same case as with "bring".
8. **DELIVER:** a subset of "give", same case as "bring".
9. **DISTRIBUTE:** a subset of "give". Giving does not imply distributing, but distributing necessarily implies giving.
10. **DIVIDE:** a subset of "share". Sharing does not imply dividing, but dividing necessarily implies sharing.
11. **DONATE:** prominent verb.
12. **DROP (OFF):** a subset of "give", same case as with "bring".
13. **EXCHANGE:** prominent verb.
14. **FETCH:** a subset of "take". Fetching is a forced way of taking, usually with a big motion involved.
15. **GIVE:** prominent verb.
16. **HAND (OVER):** a subset of "give", same case as with "bring".
17. **LEASE:** a subset of "lend". Leasing is a special type of lending, referring typically to homes and cars as the possession item.
18. **LEND:** prominent verb.
19. **OFFER:** a subset of "give", same case as "bring".
20. **PROVIDE:** a subset of "give", same case as "bring".
21. **ROB:** a subset of "steal". These are subtle synonyms but "steal" covers more diverse contexts. Robbing is a type of theft.
22. **RETURN:** a subset of "give", it is the act of giving back. Returning must be preceded by an act of taking, or one of its synonyms, in the history of events.
23. **SEIZE:** a subset of "take". Seizing is forceful way of taking away a possession from its owner, usually resulting from not following a law. In certain cases, the possession will be given back to the rightful owner after a period of time.
24. **SELL:** prominent verb.
25. **SHARE:** prominent verb.

26. **SNATCH:** a subset of "take". Snatching is a way of taking, typically done in a very rapid manner.
27. **STEAL:** prominent verb.
28. **SUPPLY:** a subset of "give", same case as "bring".
29. **SUSPEND:** a subset of "take". Suspending is a non-forceful way of taking away a possession from its owner, usually resulting from not following a law. In certain cases, the possession will be given back to the rightful owner after a period of time.
30. **TAKE:** prominent verb.
31. **TRADE:** a subset of "exchange". These are subtle synonyms but "exchange" covers more diverse contexts. Trading is a type of exchange.

There is 1 unique verb of importance which is not found above, it is the verb representing an act of exchange where there is an a priori agreement but the end result is different from the initial agreement. The case of swindling a trade. This will be the last prominent verb to be added:

Swindle: prominent verb.

The 11 prominent transfer of possession verbs determined are:

- Exchange
- Sell
- Buy
- Swindle
- Donate
- Give
- Take
- Steal
- Share
- Lend

- Borrow

The identification of these verbs of interest allows me to find a way to capture their mapping to the physical world in a uniform representation. The synonyms get classified in the hierarchy into subsets. A schematic of the hierarchy developed is presented in the figure on the following page.

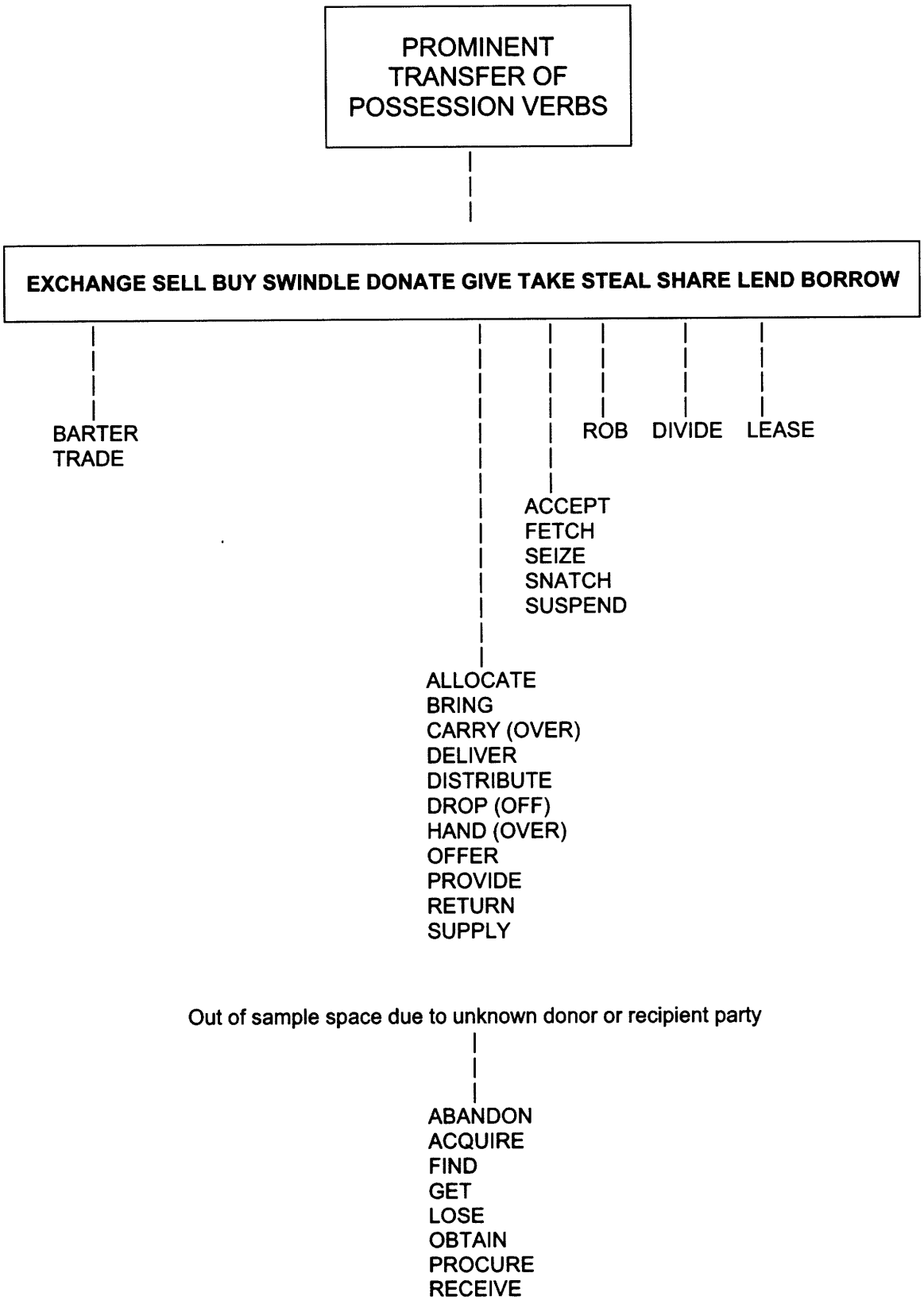

Figure 3-2. List of prominent transfer of possession verbs and hierarchy.

3.3.4 Possession Space

As discussed in section 3.2, I split the discussion in two sections: the cases of physical and abstract possession. To facilitate the modeling process, I will first develop the representative model for the possession space of physical possession. I will then use this to derive very simply the representative model for the possession space of abstract possession. This culminates to the aggregation of both sub-models into one all-inclusive model.

3.3.4.1 Possession Space Model for Physical Possession

A transfer of possession (e.g. giving) is seen as a movement from one party to another in an abstract space – the "possession" space. To define this possession space, we must answer the following question:
What are the factors that allow us to distinguish between all the various cases of physical possession transfer?
These factors will be denoted as the dimensions of the possession space.

I have defined 3 dimensions for possession. I chose them in such a way not to have too much complexity, keeping the model simple but not trivial. These three dimensions combined can represent all cases of possession transfer. Physical state represents who has what and who is giving something. Mental state represents if the parties are better or worse off after the transfer. Desire represents if the parties are willing or not to transfer the possession in question. The following four key examples will explain this very clearly.

A	↔	B
+		+
D		D

Exchange/Sell/Buy

A	↔	B
+		–
D		D

Swindle

Figure 3-3. Key examples describing physical possession transfer.

In each schematic, the upper row represents physical state, the middle one represents mental state, and the lower one represents desire. The arrows show the direction of the transfer. The + and – signs indicate if the agents involved in the transfer are better or worse off after the transfer occurred, respectively. The D and ND signs indicate if the agents desired the transfer to occur or not, respectively.

As can be seen by analyzing the upper two figures, the only difference between "exchange/sell/buy" and "swindle" is that in the case of swindle one of the agents is worse off after the transfer occurs. This is exactly the representation we want, as it is compatible with how we define these verbs. Thus, the dimension of "mental state" is the key factor in determining whether an instance of "exchange/sell/buy" or "swindle" has occurred.

Similarly, by analyzing the lower two figures, the only difference between "give/take" and "steal" is that in the case of steal one of the agents has no desire for the transfer to occur. This is exactly the representation we want, as it is compatible with how we define these verbs. Thus, the dimension of "desire" is the key factor in determining whether an instance of "give/take" or "steal" has occurred.

With the dimensions of physical possession space defined, schematics for each of the prominent verbs can be drawn. Refer to

Appendix A for the complete set of diagrams for each of the prominent verbs in possession space.

3.3.4.2 Possession Space Model for Abstract Possession

As explained in the beginning of the section for defining our possession space, there is only 1 difference between physical possession and abstract possession. One deals with tangible items while the other deals with intangible items. However, while these may be differing objects in nature, our model remains unaffected. The same possession space exists in modeling abstract possession. Let us use the following example:

Bill (A) gave Jane (B) an idea.

This possession transfer for the prominent verb "give/take" can be modeled as such:

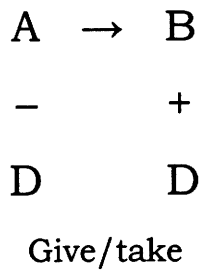

Figure 3-4. Key example describing abstract possession transfer.

The 3 dimensions for the possession space defined in the case of physical possession are also valid here. Physical state represents who has what and who is giving something. In our example, A is giving B the, intangible item, idea. Mental state represents if the parties are better or worse off after the transfer. Party B is better off by gaining an idea and A is potentially worse off by giving this knowledge with B. Desire represents if the parties are willing or not to transfer the possession in question. With A giving B an idea being an intentional event, there is a will on both ends to receive and give.

Thus, we can draw from the representation built to describe the possession space for physical possession to build the one for abstract possession. As exemplified above, the same dimensions hold true to distinguish between the nuances of all the prominent verbs. Therefore, it can be safely established that the possession space is the same.

With the dimensions of physical possession space discovered to be identical to what was developed in 3.3.4.1, the complete set of diagrams for each of the prominent verbs in possession space can also be seen in Appendix A.

3.3.4.3 Possession Space Model

Sections 3.3.4.1 and 3.3.4.2, where the 2 conceptual sub-models were built for the cases of physical and abstract possession, allow us to build an aggregate model encompassing both types of possession. This possession space is going to be the weighted combination of both sub-models. Since our 2 previous sections demonstrate that the sub-models are identical, merely differing conceptually, the possession space is identical to what was developed in 3.3.4.1.. Our results indicate that the schematics for all prominent verbs for all cases have already been discovered from 3.3.4.1 and defined in Appendix A. Refer to Appendix A for the complete set of diagrams for each of the prominent verbs in possession space.

3.3.5 Building Learning Templates and Redefining Possession Space

Observing Appendix A, we see that there are 2 cases where prominent verbs have the same representation – exchange and sell/buy as well as give/take and lend/borrow. The representation needs to be improved such that the ambiguity is no longer present. A feasible solution is to make use of Gary Borchardt's transition space

representations. Each of the prominent verbs gets a transition space representation "TSR" template.

There also needs to be a way to distinguish between the representations of 3 cases: give and take, sell and buy, and lend and borrow. These 3 cases of pairs can be seen as equivalent if the notion of perspective is dismissed. Perspective cannot be ignored in real life and must be accounted for. An addition to a TSR template could be a slot for specifying the party initiating the motion, call it "Moving". The slot serves to characterize if party A, B, or both are initiating and dominating the motion. Using give and take as an example:

Without perspective:

A gives B is equivalent to B takes from A.

With the added slot to identify the main actor moving:

If "Moving" = A, representation is of the action to "give".

If "Moving" = B, representation is of the action to "take".

Adding this slot to the TSR templates should yield an accurate representation of possession transfer.

The best way to illustrate what these templates are is with a concrete example. I have drawn out – as a table – 2 actions: "sell" and "barter". They are shown in the figure on the following page. Note that "barter" falls in the hierarchy under the prominent verb "exchange" and is represented in the same way in the possession space.

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∄	∅
Mental A	∄	∄	↑	∄
Desire A	A	∅	∅	∅
IOU A	∄	∄	∄	∄
Money	∄	∄	↑	∄
Poss. B	∄	∄	A	∅
Mental B	∄	∄	↑	∄
Desire B	A	∅	∅	∅
IOU B	∄	∄	∄	∄
Money	∄	↓	∄	∄

Moving: A

Sell

	t_1	t_2	t_3	t_4
Poss. A	∅	D	A	∅
Mental A	∄	∄	↑	∄
Desire A	A	∅	∅	∅
IOU A	∄	∄	∄	∄
Money	∄	∄	∄	∄
Poss. B	∅	D	A	∅
Mental B	∄	∄	↑	∄
Desire B	A	∅	∅	∅
IOU B	∄	∄	∄	∄
Money	∄	∄	∄	∄

Moving: AB

Barter (in Exchange stack)

Figure 3-5. TSR templates for sell and barter.

The columns are the time points, which, as mentioned earlier in section 2.2, are delineated not by absolute time but by qualitative changes of state. The rows are the dimensions of the possession space. As seen by the items highlighted in yellow, the key difference between the two templates, the salient feature that would allow a program to differentiate the case of barter from that of selling (or buying if the case was considered), is how money is not a changing factor in barter whereas it is in sell (or buy).

3.4 Descriptors of the Representation

Looking back at the templates above, there are 6 dimensions needed in the possession space if we are to have a unique representation

for each prominent verb. This avoids what we found in section 3.3.4 for the cases of exchange and sell/buy as well as give/take and lend/borrow. These dimensions are: physical state, mental state, desire, IOU, money, and moving.

Physical state, mental state, and desire capture the same qualitative state changes as in our model of possession space from section 3.3.4..

IOU, "I Owe You", is a dimension which serves to point out if there is a possession transfer between the parties that is agreed upon to be temporary from the start. This is the salient feature that would allow a machine to detect between the case of give/take and lend/borrow. In the case of give/take, IOU never appears for none of the parties. In the case of lend/borrow, "IOU" appears and consequently disappears by the end of the event for both parties. Refer to Appendix B for these eight TSR templates.

Money is a dimension simply serving to distinguish between a transfer of two possessions involving money or not. It was shown at the beginning of this section how money is the salient feature in how a machine would learn and know the difference between the prominent verbs sell/buy, where a possession is given in return for money, and the prominent verb "exchange" (example used barter), where 2 possessions are being exchanged with no money. In the possession space of 3 dimensions from section 3.3.4., a machine would have no way to differentiate between the two cases. An additional comment to keep in mind about the "Money" dimension is that any of the possession transfers can involve money. An example of this would be:

Bill donated a scarf to the salvation army.

Bill donated money to Jane's foundation.

The first event pertains to a donation of an object. The second one pertains to a donation of money. For the latter case, the template would be slightly different from the standard one merely in the sequences of

moments for the Money row. I have drawn out the templates for these 2 scenarios in the figure below.

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∄	∄
Mental A	∄	↑	∄	∄
Desire A	A	∅	∅	∅
IOU A	∄	∄	∄	∄
Money	∄	∄	∄	∄
Poss. B	∄	∄	A	∅
Mental B	∄	∄	↑	∄
Desire B	A	∅	∅	∅
IOU B	∄	∄	∄	∄
Money	∄	∄	∄	∄

Moving: A

Donate an item (not money)

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∄	∄
Mental A	∄	↑	∄	∄
Desire A	A	∅	∅	∅
IOU A	∄	∄	∄	∄
Money	∄	↓	∄	∄
Poss. B	∄	∄	A	∅
Mental B	∄	∄	↑	∄
Desire B	A	∅	∅	∅
IOU B	∄	∄	∄	∄
Money	∄	∄	↑	∄

Moving: A

Donate an item (money)

Figure 3-6. TSR templates for donate. Non-money and money item cases.

As seen above, the 2 templates do not vary in any other row but Money. The same double-case situation can apply to any of the prominent verbs with the exception of exchange, sell, and buy. Why? Because parties can exchange money, but even if they do, it is exchanged evenly and so the "Money" state never changes qualitatively nor quantitatively. If money is exchanged unevenly, it would no longer be written as an exchange in the English language but rather a swindle – a "money swindle". Thus, the 2 templates for the case of an exchange of money and the case of an exchange of a non-money item would be

identical and redundant. Only 1 template is required as we are concerned in this work only with the acquisition of knowledge about possession and its transfers, not the nature of the possession item in question. Our second exception, sell and buy, automatically implies a usage of money in the English language. There is only 1 template covering each of the sell and buy cases, where the item is money. The non-money item cases do not make sense based on the semantics of the English language.

Having covered the 2 exceptions, we are left with donate, steal, swindle, give, take, lend, borrow, and share that have double-cases. The formation of these templates and their differences , per prominent verb, can be developed with the same methodology as used for the example of "donate" described above. Refer to Appendix B for the full set of TSR templates for all the prominent verbs, including all the double-cases.

As a result of the work in this section, we now have a comprehensive model to represent the transfer of possession in the physical world. Machines simply need to inherit each of the 19 TSR templates from Appendix B to understand any possible scenario of possession transfer, whether in the context of physical or abstract possession. There are 19 templates because there are 11 prominent transfer of possession verbs, of which 8 have double cases depending if a money or non-money item is involved in the transfer; i.e., 8 * 2 + 3 = 19. These 19 templates can allow us and machines to ground the abstract notion of possession in the physical world, in a possession space world where there exist 6 dimensions and 10 qualitative state change attributes. In the following chapter, the value of this representation is demonstrated and discussed.

Chapter 4

Discussion

4.1 Learning the Representation

4.1.1 Salient features

By comparing the 19 templates, we can distinguish the salient features making the various descriptions unique from one another. Upon analysis, the following can be said:

1. "Lend" and "borrow" are the same descriptions but with opposing parties for "Moving".
2. "Lend" has the same description as "give" but with the salient difference that an IOU appears and then disappears in its sequence. IOU is a constant never appearing in any of the events except for "lend" and "borrow".
3. "Borrow" has the same description as "take" but with the salient difference that an IOU appears and then disappears in its sequence. IOU is a constant never appearing in any of the events except for "lend" and "borrow".
4. "Give" and "take" are the same descriptions but with opposing parties for "Moving".
5. "Steal" has the same description as "take" with the exception that "Desire" never appears for party A (the one being stolen from), whereas it appears and never disappears for both parties in "take".
6. "Donate" has the same description as "give" with the exception that "Mental" increases for party A (the donor) upon transferring the

possession to B, whereas it decreases for party A (the giver) in the moment of transfer.

7. "Sell" and "buy" are the same descriptions but with opposing parties for "Moving".
8. Exchange" has a similar description to "sell" and "buy" with 3 misses. "Moving" is AB for "exchange" but just 1 party for "sell" and "buy", "Money" is never changing for "exchange" but increasing and decreasing for "sell" and "buy". Thirdly, in "exchange", both parties begin with a possession which then gets swapped. This is in contrast to the cases of "sell" and "buy, where party B, the one paying for the possession, does not have "Possession" appear until t_3, once the transaction occurs.
9. "Swindle" has the same description as "exchange" but with the difference that party (B), the one being swindled out of, has a decrease in "Mental" and a disappearing "Desire" upon realizing what has occurred.
10. "Share" has the most distinguished features in the group. It is most similar to "exchange" but with 3 differences. The parties that "share" become better off, increase in "Mental" for A and B, as of t_1. For "exchange", "Mental" increases for A and B only at t_3. "Money" never changes in "exchange" regardless of what is being exchanged. For "share", if money is the item in question being shared, party A, the one sharing, has a "Money" decrease and party "B" has a "Money" increase. Lastly, for the case of "share", party A never sees "Possession" disappear and party B sees "Possession" appear at t_1 and never disappear at future time points. This is different from the case of "exchange", where both parties begin with a possession which then gets swapped. This translates into "Possession" for both parties which does not disappear, disappears, appears, and finally does not disappear.

4.1.2 Summarizing with a Decision Tree

Having established the salient features for the 11 verbs, I can form a decision tree which would allow for learning by evaluation of the presence or absence of these features. The resulting tree that satisfies the 10 conditions described above is shown in the figure below.

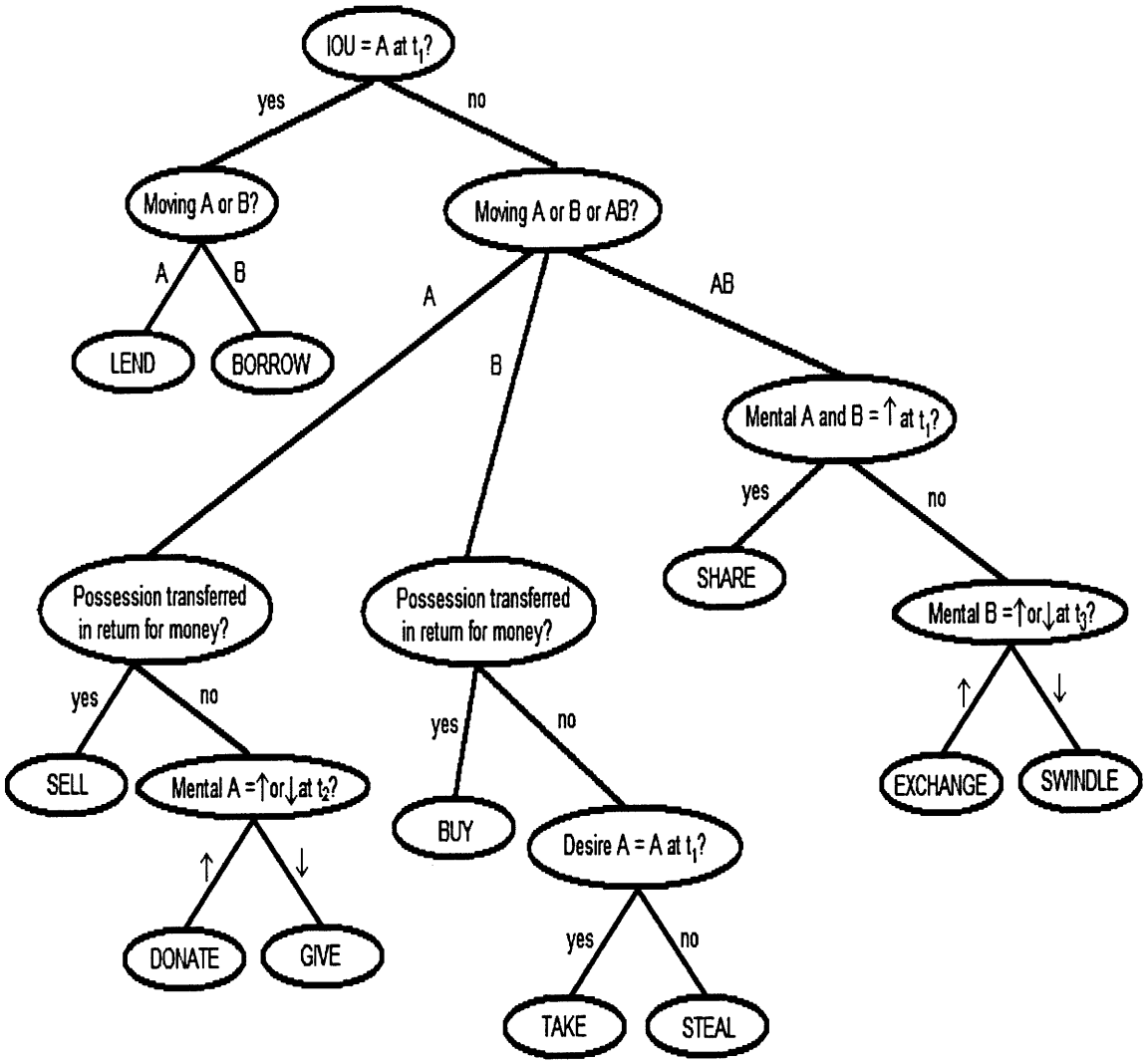

Figure 4-1. Decision tree for learning via questioning of presence or absence of salient features.

4.1.3 Learning from Near-Miss Examples

A way to learn these representations is by making use of near-miss learning techniques discussed in section 2.3. With the tree created in section 5.2, many sets of near-miss examples surface, representations differing in mostly 1 aspect only. I will go over 2 such examples.

"Steal" is a near-miss example of "take". Inputting the "take" event template as the initial model and then presenting the system with the "steal" event template, the system would deduce the require-link of "Desire A appears" for "take".

"Give" is a near-miss example of "lend". Inputting the "lend" event template as the initial model and then presenting the system with the "give" event template, the system would deduce the forbid-links of "IOU A appears" and "IOU B appears" for "give".

Progressing with more and more examples would allow the system to evolve and learn all representations. These 2 examples are enough to illustrate the concept here. The knowledge of the system can be learned with this technique. It appears to be very well-suited to the representations developed given that the salient features differ by a minimal number between the prominent possession transfer verbs.

4.2 Summarizing 10 Questions that Can and a Few Ones that Cannot Be Answered by the System

My model allows for a system to answer the following questions:

1. Who is the primary moving party, or actor?
   This can be answered by looking at the "Moving" dimension. It could be A, B, or AB.
2. Who owned a possession at the start of the event?
   This can be answered by observing t_1 and checking which of "Possession A" and "Possession B" have the slot filled out as "does not disappear". It could be A, B, or AB.

3. Who owned the possession by the end of the event?
   This can be answered by observing t_4 and checking which of "Possession A" and "Possession B" have the slot filled out as "does not disappear". It could be A, B, or AB.
4. How many possessions were involved in the transfer?
   This can be answered by observing t_1 and counting how many of the slots are filled out as "does not disappear" for "Possession A" and "Possession B". It could be 1 or 2.
5. Were each of the parties' better or worse off by the end of the event?
   This can be answered by checking if "Mental" has increased or decreased for each of the parties. If "Mental" increases, the party is better off. If "Mental" decreases, the party is worse off.
6. Did each of the parties involved desire the event's occurrence?
   This can be answered by checking if "Desire" for each of the parties "appears" in one of the time points. For those parties where the answer is yes, the desire for the event was present. If "Desire" "does not appear" in any of the time points for one of the party's in question, that party did not desire the event to occur.
7. Was there a case of an initial desire being present but then going away for one of the parties throughout the event?
   This can be answered by verifying if one of the parties' "Desire" "appears" and then "disappears", at time points t_1 and t_3, respectively. If so, then the answer is yes. This also indicates the event that has occurred is "swindle".
8. Was there a transfer of money as part of the event?
   This can be answered by checking if "Money" does not change across all time columns for each of the parties. If it changes for at least one of the 2 parties, then there was a transfer of money.
9. Did the parties involved become richer, poorer, or with the same financial status?

This can be answered by observing if "Money" has increased, decreased, or not changed throughout the event for each of the parties. For a given party, if it has increased, the party is richer. If it has decreased, the party is poorer. Finally, with no change, the party maintains the same financial status.

10. Is the transfer of possession event observed a temporary one?
    This can be answered by checking if "IOU" appears for both parties A and B at t_1. If yes, the transfer is temporary and based on an agreement that you must return or reclaim your possession, depending on which party you are. This also indicates the event that has occurred is "lend" or "borrow", depending on who the moving party is.

While the system exemplified how it can be useful in answering many important questions about events, there are a few questions which cannot be answered with the given representation. I list 5 below:

1. Why is a party's mental state better off upon donating a possession to another party?
2. Are the possessions being transferred going to last or will they perish at a future point in time? Considering this question, is it truly a "permanent" ownership, if we are excluding the cases of "lend" and 'borrow"?
3. Do parties A and B know each other prior to the event?
4. How old are the possessions being transferred?
5. What is the value of each of the possessions?

4.3 Correlation Between the Representation and Visual Events

I have explained thus far how this representation is of value in distinguishing the salient features to allow for near-miss learning and

decision-making about possession transfer events, as well as in answering many questions about these events. This representation can be put to service in a third way; it can be of value in helping a visual system determine what's going on in the world. Specifically, the representation can support the visual determination of the appropriate possession transfer verb.

When a visual system observes a possession transfer event, it can see which party is, or parties are, moving. This corresponds to my "Moving" dimension in the representation.

When it sees an item held by a party, it knows that the party in question possesses an item at that time point. This corresponds to my "appear" or "does not disappear" in the "Possession" slot for the given party in the representation.

When parties are seen smiling, it can be deduced that they are in a better off state and expressing desire, typically with a new ownership of possession or an increase in money status. This corresponds to the "Mental" increasing, "Desire" appearing", "Possession" appearing, and "Money" increasing. To generalize this case, the facial expression of a party – smile or frown or shock or anger, can be correlated to my dimensions of mental state, desire, possession, and money in the representation.

I imagine a visual system observing the following event:

Bill (A) gives Jane (B) his book.

In the visual world, A would be seen moving towards B with the "car". A and B would both be smiling initially. At the end of the transfer, neither A nor B would express anger, shock, or rage. The visual system would infer the desire is present for both A and B. A would be seen transferring over a possession while getting nothing back, not a possession nor money. The visual system could then understand that A is worse off but B is better off. With the facts that A was moving towards B and A gave a possession to B without receiving one back, the system can deduce that

the event it has just observed is A giving B a possession. This is in complement agreement with my representation. I can conclude that this result allows my representation to be very useful in helping a visual system determine what's going on in the world and identify possession transfer events occurring.

While the correlation between my representation and visual events to identify the suitable possession verb is high, there is a special circumstance where both the representation and the visual world fail. This is the first question listed in the set of questions that cannot be answered by the system:

Why is a party's mental state better off upon donating a possession to another party?

In the representation, "Mental" A increasing would be counterintuitive to the fact that it is giving away a possession without getting anything back. In the visual world, as A would donate to B, one would see A looking happy and B looking happy upon receiving the donation. There would be no indication once again of why A seems to be better off as a result of the transfer.

The solution would be to find a way to let the visual system and representation understand that A feels joy from the charity to make B better off, in turn making A better off.

While the ability to understand why "donate" leaves the donor mentally better off is a difficult notion to incorporate in the representation or in a visual system, I have still shown how there is great value in using my representation to help a visual system in classifying and understanding possession transfer events.

Chapter 5

Future Work

While this work provides a step towards learning how to replicate human intelligence for machines where abstract notions are concerned, there is much more that can be explored with the developed technique created. Grounding the abstract world in the physical world can be of great help in several areas. There are also a few concepts which can be elaborated on to create more completeness. With some effort, I believe there are a number of ways my work can be extended and improved.

5.1 Abstract, Intangible, Possession Items

While possession transfers involving an "abstract" or intangible item are represented with the same TSRs as in the case of a "physical" or tangible item, the correlation between the representation and visual events no longer really applies. If a visual system is observing Jane give a "cold" to Bill, it will get confused and not see any "physical" item move in the visual world. An extension of this work could be to find a way to preserve the utility of the representation in aiding a visual system to understand what abstract possession transfers are occurring.

5.2 The case with Unknown Recipients or Sources

The scope of this work did not consider any transfer of possession to an unknown recipient or from an unknown source. That is, I built representations for possession transfers occurring between, from, and to

explicit parties – whether these parties depict people or places. This removed from my consideration the following verbs:

abandon, acquire, find, get, lose, obtain, procure, receive

An area of improvement in this work to render it more comprehensive is to find a representation for this case where the verbs can only specify a recipient or donor of the possession with additional context.

5.3 Why is a Party Donating with a Better Off Mental State?

This question has been addressed in the previous chapter. As discussed, neither the representation nor a visual system would be able to detect this even by observing the template or the actions in the event and the facial expressions.

It is hard to understand why a party that is giving away a possession without getting one back nor money could be mentally better off. Intuition would lead one to believe that the representation should point to the case of "give".

It has been established that this is a fairly difficult concept to include in the representation or in the visual system. Nonetheless, it is worth noting solving this lacking piece of information at a future point in time would be an added feature that would increase the accuracy of my representation.

5.4 The Question of Perishable Goods

While the steps I went through to implement my model of possession space have been very thorough and not allowing for nearly any assumptions, there is 1 area that was not considered. What if the items of possession in question perish or, better said, are not durable? Take the example of the possession of "food". If Bill shares his toy with Jane, they both can keep the toy forever provided they take care of it.

However, if Bill shares his dinner with Jane, it is clear the food will be eaten and gone. In my implementation of the model with TSR templates, this translates to a difference in what I've designed. Possession for Bill and Jane, physical state for parties A and B, will eventually disappear "D". This is something which as of current is not built into my model. While the cases of non-durable goods is rather seldom, it is still worthwhile to add a feature so that a machine could distinguish this special case and not get confused by seeing a different TSR than the ones created in this work.

Chapter 7

Contributions

- Identified a list of 11 prominent possession transfer verbs – established a hierarchy to classify other verbs pertaining to possession transfer

- Devised a concrete representation grounded in the physical world of the abstract notion of possession and identified 6 dimensions to define the possession space – the possession space encompassing both physical and abstract possession

- Delivered a tabular mapping of each type of possession transfer – designed 19 TSR learning templates covering all prominent verbs and all cases in possession space

- Explained via two descriptive examples how near-miss learning can be used as a learning technique

- Delivered a list of ten questions, along with their answers, that the system can answer given my representation

- Argued the utility of my representation in interpreting visual events

Appendix A

Representation of Prominent Verbs in Possession Space

1. EXCHANGE & SELL/BUY

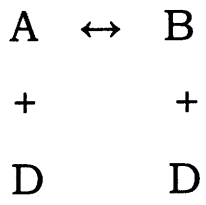

Figure A-1. Exchange & sell/buy simplistic schematic representation in possession space.

2. SWINDLE

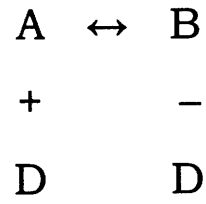

Figure A-2. Swindle simplistic schematic representation in possession space.

3. DONATE

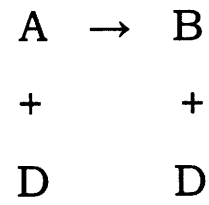

Figure A-3. Donate simplistic schematic representation in possession space.

4. GIVE/TAKE & LEND/BORROW

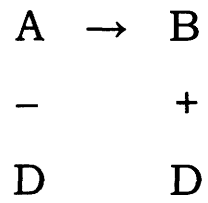

Figure A-4. Give/take & lend/borrow simplistic schematic representation in possession space.

5. STEAL

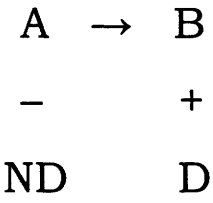

Figure A-5. Steal simplistic schematic representation in possession space.

6. SHARE

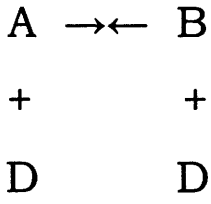

Figure A-6. Share simplistic schematic representation in possession space.

Appendix B

Transition State Representation Templates of Prominent Verbs for All Cases in Possession Space

1. EXCHANGE – MONEY AND NON-MONEY ITEM CASES IDENTICAL

Bill (A) exchanged his scarf with Jane's (B) gloves.

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	A	Ø
Mental A	Δ	Δ	↑	Δ
Desire A	A	Ø	Ø	Ø
IOU A	✗	✗	✗	✗
Money	Δ	Δ	Δ	Δ
Poss. B	Ø	D	A	Ø
Mental B	Δ	Δ	↑	Δ
Desire B	A	Ø	Ø	Ø
IOU B	✗	✗	✗	✗
Money	Δ	Δ	Δ	Δ

Moving: AB

Table B-1. Exchange TSR template for money/non-money item cases.

2. SELL – MONEY ITEM CASE, NON-MONEY ITEM CASE NOT VALID

Bill (A) sold a car to Jane (B).

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Δ	Δ	↑	Δ
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Δ	Δ	↑	Δ
Poss. B	Ø	Ø	A	Ø
Mental B	Δ	Δ	↑	Δ
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Δ	↓	Δ	Δ

Moving: A

Table B-2. Sell TSR template for money item case.

3. BUY – MONEY ITEM CASE, NON-MONEY ITEM CASE NOT VALID

Jane (B) bought a car from Bill (A).

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∅	∅
Mental A	∅	∅	↑	∅
Desire A	A	∅	∅	∅
IOU A	∅	∅	∅	∅
Money	∅	∅	↑	∅
Poss. B	∅	∅	A	∅
Mental B	∅	∅	↑	∅
Desire B	A	∅	∅	∅
IOU B	∅	∅	∅	∅
Money	∅	↓	∅	∅

Moving: B

Table B-3. Buy TSR template for money item case.

4. SWINDLE – NON-MONEY ITEM CASE

Bill (A) swindled Jane (B) into giving him an additional scarf in their trade.

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	A	Ø
Mental A	Δ	Δ	↑	Δ
Desire A	A	Ø	Ø	Ø
IOU A	✗	✗	✗	✗
Money	Δ	Δ	Δ	Δ
Poss. B	Ø	D	A	Ø
Mental B	Δ	Δ	↓	Δ
Desire B	A	Ø	D	✗
IOU B	✗	✗	✗	✗
Money	Δ	Δ	Δ	Δ

Moving: AB

Table B-4. Swindle TSR template for non-money item case.

5. SWINDLE – MONEY ITEM CASE

Bill (A) swindled the hotel (B) out of $10000.

	t_1	t_2	t_3	t_4
Poss. A	∅	D	A	∅
Mental A	∅	∅	↑	∅
Desire A	A	∅	∅	∅
IOU A	∅	∅	∅	∅
Money	∅	∅	↑	∅
Poss. B	∅	D	A	∅
Mental B	∅	∅	↓	∅
Desire B	A	∅	D	∅
IOU B	∅	∅	∅	∅
Money	∅	∅	↓	∅

Moving: AB

Table B-5. Swindle TSR template for money item case.

6. DONATE – NON-MONEY ITEM CASE

Bill (A) donated his clothes to the salvation army (B).

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Δ	↑	Δ	Δ
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Δ	Δ	Δ	Δ
Poss. B	Ø	Ø	A	Ø
Mental B	Δ	Δ	↑	Δ
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Δ	Δ	Δ	Δ

Moving: A

Table B-6. Donate TSR template for non-money item case.

7. DONATE – MONEY ITEM CASE

Bill (A) donated $500 to Jane's foundation (B).

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Ø	↑	Ø	Ø
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Ø	↓	Ø	Ø
Poss. B	Ø	Ø	A	Ø
Mental B	Ø	Ø	↑	Ø
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Ø	Ø	↑	Ø

Moving: A

Table B-7. Donate TSR template for money item case.

8. GIVE – NON-MONEY ITEM CASE

Bill (A) gave Jane (B) a hat.

	t_1	t_2	t_3	t_4
Poss. A	∅	D	∅	∅
Mental A	∅	↓	∅	∅
Desire A	A	∅	∅	∅
IOU A	∅	∅	∅	∅
Money	∅	∅	∅	∅
Poss. B	∅	∅	A	∅
Mental B	∅	∅	↑	∅
Desire B	A	∅	∅	∅
IOU B	∅	∅	∅	∅
Money	∅	∅	∅	∅

Moving: A

Table B-8. Give TSR template for non-money item case.

9. GIVE – MONEY-ITEM CASE

Bill (A) gave Jane (B) $20.

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Δ	↓	Δ	Δ
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Δ	↓	Δ	Δ
Poss. B	Ø	Ø	A	Ø
Mental B	Δ	Δ	↑	Δ
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Δ	Δ	↑	Δ

Moving: A

Table B-9. Give TSR template for money item case.

10. TAKE – NON-MONEY ITEM CASE

Jane (B) took Bill's (A) hat.

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Δ	↓	Δ	Δ
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Δ	Δ	Δ	Δ
Poss. B	Ø	Ø	A	Ø
Mental B	Δ	Δ	↑	Δ
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Δ	Δ	Δ	Δ

Moving: B

Table B-10. Take TSR template for non-money item case.

11. TAKE – MONEY-ITEM CASE

Jane (A) took $20 from Bill (B).

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Ø	↓	Ø	Ø
Desire A	A	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Ø	↓	Ø	Ø
Poss. B	Ø	Ø	A	Ø
Mental B	Ø	Ø	↑	Ø
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Ø	Ø	↑	Ø

Moving: B

Table B-11. Take TSR template for money item case.

12. LEND – NON-MONEY ITEM CASE

Bill (A) lent Jane (B) his car.

	t_1	t_2	t_3	t_4	t_5	t_6
Poss. A	∅	D	∄	∄	A	∅
Mental A	∄	↓	∄	∄	↑	∄
Desire A	A	∅	∅	∅	∅	∅
IOU A	A	∅	∅	∅	D	∄
Money	∄	∄	∄	∄	∄	∄
Poss. B	∄	∄	A	D	∄	∄
Mental B	∄	∄	↑	↓	∄	∄
Desire B	A	∅	∅	∅	∅	∅
IOU B	A	∅	∅	∅	D	∄
Money	∄	∄	∄	∄	∄	∄

Moving: A

Table B-12. Lend TSR template for non-money item case.

13. LEND – MONEY ITEM CASE

Bill (A) lent Jane (B) $50.

	t_1	t_2	t_3	t_4	t_5	t_6
Poss. A	∅	D	∅	∅	A	∅
Mental A	∅	↓	∅	∅	↑	∅
Desire A	A	∅	∅	∅	∅	∅
IOU A	A	∅	∅	∅	D	∅
Money	∅	↓	∅	∅	↑	∅
Poss. B	∅	∅	A	D	∅	∅
Mental B	∅	∅	↑	↓	∅	∅
Desire B	A	∅	∅	∅	∅	∅
IOU B	A	∅	∅	∅	D	∅
Money	∅	∅	↑	↓	∅	∅

Moving: A

Table B-13. Lend TSR template for money item case.

14. BORROW – NON-MONEY ITEM CASE

Jane (B) borrowed Bill's (A) car.

	t_1	t_2	t_3	t_4	t_5	t_6
Poss. A	∅	D	∅	∅	A	∅
Mental A	∅	↓	∅	∅	↑	∅
Desire A	A	∅	∅	∅	∅	∅
IOU A	A	∅	∅	∅	D	∅
Money	∅	∅	∅	∅	∅	∅
Poss. B	∅	∅	A	D	∅	∅
Mental B	∅	∅	↑	↓	∅	∅
Desire B	A	∅	∅	∅	∅	∅
IOU B	A	∅	∅	∅	D	∅
Money	∅	∅	∅	∅	∅	∅

Moving: B

Table B-14. Borrow TSR template for non-money item case.

15. BORROW – MONEY ITEM CASE

Jane (B) borrowed $50 from Bill (A).

	t_1	t_2	t_3	t_4	t_5	t_6
Poss. A	∅	D	∅	∅	A	∅
Mental A	∅	↓	∅	∅	↑	∅
Desire A	A	∅	∅	∅	∅	∅
IOU A	A	∅	∅	∅	D	∅
Money	∅	↓	∅	∅	↑	∅
Poss. B	∅	∅	A	D	∅	∅
Mental B	∅	∅	↑	↓	∅	∅
Desire B	A	∅	∅	∅	∅	∅
IOU B	A	∅	∅	∅	D	∅
Money	∅	∅	↑	↓	∅	∅

Moving: B

Table B-15. Borrow TSR template for money item case.

16. STEAL – NON-MONEY ITEM CASE

Bill (B) stole Jane's (A) toy.

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	⚡	⚡
Mental A	⚠	↓	⚠	⚠
Desire A	⚡	⚡	⚡	⚡
IOU A	⚡	⚡	⚡	⚡
Money	⚠	⚠	⚠	⚠
Poss. B	⚡	⚡	A	Ø
Mental B	⚠	⚠	↑	⚠
Desire B	A	Ø	Ø	Ø
IOU B	⚡	⚡	⚡	⚡
Money	⚠	⚠	⚠	⚠

Moving: B

Table B-16. Steal TSR template for non-money item case.

17. STEAL – MONEY ITEM CASE

The robber (B) stole $200 from the convenience store (A).

	t_1	t_2	t_3	t_4
Poss. A	Ø	D	Ø	Ø
Mental A	Ø	↓	Ø	Ø
Desire A	Ø	Ø	Ø	Ø
IOU A	Ø	Ø	Ø	Ø
Money	Ø	↓	Ø	Ø
Poss. B	Ø	Ø	A	Ø
Mental B	Ø	Ø	↑	Ø
Desire B	A	Ø	Ø	Ø
IOU B	Ø	Ø	Ø	Ø
Money	Ø	Ø	↑	Ø

Moving: B

Table B-17. Steal TSR template for money item case.

18. SHARE – NON-MONEY ITEM CASE

Bill (A) shared his house with Jane (B).

	t_1	t_2	t_3	t_4
Poss. A	∅	∅	∅	∅
Mental A	↑	∆	∆	∆
Desire A	A	∅	∅	∅
IOU A	✗	✗	✗	✗
Money	∆	∆	∆	∆
Poss. B	A	∅	∅	∅
Mental B	↑	∆	∆	∆
Desire B	A	∅	∅	∅
IOU B	✗	✗	✗	✗
Money	∆	∆	∆	∆

Moving: AB

Table B-18. Share TSR template for non-money item case.

19. SHARE – MONEY ITEM CASE

Bill (A) shared his money from his bank account with Jane (B).

	t_1	t_2	t_3	t_4
Poss. A	Ø	Ø	Ø	Ø
Mental A	↑	Δ	Δ	Δ
Desire A	A	Ø	Ø	Ø
IOU A	A	A	A	A
Money	↓	Δ	Δ	Δ
Poss. B	A	Ø	Ø	Ø
Mental B	↑	Δ	Δ	Δ
Desire B	A	Ø	Ø	Ø
IOU B	A	A	A	A
Money	↑	Δ	Δ	Δ

Moving: AB

Table B-19. Share TSR template for money item case.

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