Effects of Typicality on the Interpretation of Reciprocal Expressions

Nir Kerem
Effects of Typicality on the Interpretation of Reciprocal Expressions

Research Thesis

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer Science

Nir Kerem

Submitted to the Senate of the Technion — Israel Institute of Technology
Adar 5770 Haifa February 2010
The research thesis was done under the supervision of Prof. Alon Itai in the Computer Science Department.

I would like to extend my gratitude and great appreciation to Yoad Winter for his support, his passion and most of all for his patient, continuous help and guidance through this exciting endeavour. I gained so much from this experience, and feel truly privileged to have worked with him.

This work would also not have been possible without the assistance, guidance and help of Prof. Naama Friedmann of Tel Aviv University. I am furthermore grateful to Michal Biran and Ruth Noy Shapira for their help with the experimental work.

The generous financial support of the Technion and the Israel Science Foundation is gratefully acknowledged.
Contents

Abstract 1

Abbreviations and Notations 2

Semantic Meanings 4

1 Introduction 6

2 Previous Works 9
  2.1 Reciprocal interpretation .............................. 9
     2.1.1 Dalrymple et al. (1998) ............................ 9
     2.1.2 Sabato and Winter (2005) ......................... 13
  2.2 Concepts and typicality ............................... 15

3 The Maximal Typicality Hypothesis 18

4 Experimental Support for the Maximal Typicality Hypothesis 23
  4.1 Experiment 1 – Preferences of patient cardinality (picture-based) 24
  4.2 Experiment 2 – Preferences of reciprocal interpretations (picture-based) 26
  4.3 Experiment 3 – Preferences of patient cardinality (text-based) 28
  4.4 Experiment 4 – Preferences of reciprocal interpretations (text-based) 30

5 Discussion 33

6 Conclusions and Further Research 40

Abstract in Hebrew 44
List of Figures

1.1 Two situations for the expression *combing each other* . . . . . . . 8
3.1 Combing with one or two patients . . . . . . . . . . . . . . . . . . . 19
4.1 Hitting with one or two patients . . . . . . . . . . . . . . . . . . . . 25
4.2 Two additional situations for the expression *combing each other* . 27
5.1 Correlation between results of Experiments 1 and 2 . . . . . . . . 36
5.2 Correlation between results of Experiments 3 and 4 . . . . . . . . 37
5.3 Two situations for the expression *giving a speech to each other* . 39
List of Tables

4.1 Patient cardinality preference in Experiment 1  . . . . . . . . . . 26
4.2 Reciprocal interpretation preference in Experiment 2  . . . . . . 28
4.3 Preference for singular objects in Experiment 3  . . . . . . . . . 30
4.4 Preference for weaker reciprocal interpretations in Experiment 4 . 32
Abstract

The variability in the interpretation of reciprocal expressions such as each other has been extensively addressed in the literature and received detailed semantic accounts. After pointing out a central empirical limitation of previous logical accounts of reciprocity, we argue that these approaches suffer from inadequacies due to ignoring typicality preferences with binary predicate concepts. We claim that typicality preferences are crucial for interpreting reciprocal expressions and introduce a new principle, the Maximal Typicality Hypothesis (MTH), which analyzes reciprocals using an extension of the Strongest Meaning Hypothesis (SMH) proposed in Dalrymple et al.’s article “Reciprocal Expressions and the Concept of Reciprocity” (Linguistics & Philosophy 1998). Unlike the SMH, which is a principle that implicitly presupposes a classical two-valued (“definitional”) treatment of predicate concepts, the MTH respects the fuzziness of such concepts as manifested by their typicality preferences, and expects strong correlations between these preferences and the range of logical interpretations available for reciprocal expressions. To test our hypothesis, we conducted a series of psycho-linguistic experiments with speakers of Hebrew, designed to test for typicality preferences and interpretation of reciprocal expressions. The results of these experiments indicate a strong, significant correlation between typicality preferences and reciprocal interpretation, supporting the MTH.
Abbreviations and Notations

**MTH** — The Maximal Typicality Hypothesis

**SMH** — The Strongest Meaning Hypothesis

**DKKMP** — Dalrymple *et al.* (1998)

**S&W** — Sabato and Winter (2005)

**I** — The Identity relation.

\[ I \overset{\text{def}}{=} \{ (x, x) \mid x \in E \} \]

**℘(A)** — The powerset of \( A \).

\[ \wp(A) \overset{\text{def}}{=} \{ S \mid S \subseteq A \} \]

**R(x, y)** — For a binary relation \( R \), \( R(x, y) \iff (x, y) \in R \)

**R(x)** — The image of \( x \in X \) under the binary relation \( R \subseteq X \times Y \).

\[ R(x) \overset{\text{def}}{=} \{ y \in Y \mid R(x, y) \} \]

**R^v** — The symmetric closure of a binary relation \( R \).

\[ R^v \overset{\text{def}}{=} R \cup R^{-1} \]

**R^*** — The transitive closure of a binary relation \( R \).

\[ R^* \overset{\text{def}}{=} \bigcup_{t \in N} R^t \]

**R|_A** — The restriction of a binary predicate \( R \) to a set \( A \).

\[ R|_A \overset{\text{def}}{=} R \cap A^2 \]

**R \downarrow_A** — The restriction of a binary predicate \( R \) to a set \( A \) disregarding identites.

\[ R \downarrow_A \overset{\text{def}}{=} R|_A \setminus I \]

**R \subseteq_A S** — For set \( A \) and binary relations \( R \) and \( S \),

\[ R \subseteq_A S \iff R \downarrow_A \subseteq S \downarrow_A. \]

For set \( A \) and sets of binary relations \( R \) and \( S \),
$R \subseteq A S \iff \{ T \downarrow_A \mid T \in R \} \subseteq \{ T \downarrow_A \mid T \in S \}.$

$R \supseteq A S, R = A S,$ etc. are defined similarly.

$\Theta_{\text{CON}}$ — A concept CON’s typicality function.

$\Theta_{\text{CON}}$ assigns a given entity a value in the interval $[0, 1)$

according to the typicality of the entity relative to CON.

$\Theta_{\text{CON}}^{ed}$ — The semantic restriction function of the concept CON.

$\Theta_{\text{CON}}^{ed}$ assigns a given entity a value in $0, 1$ according to the

physical and logical possibility of that entity being denoted by CON.
Semantic Meanings

The following is a list of truth conditions defining different reciprocal meanings. In each one, \( A \) is the antecedent set of the reciprocal and \( R \) is the binary relation denoted by the predicate antecedent to the reciprocal expression.

\begin{align*}
\text{SR} & & \text{Strong Reciprocity} & \forall x, y \in A [y \neq x \Rightarrow R(x, y)] \\
\text{SAR} & & \text{Strong Alternative Reciprocity} & \forall x, y \in A [y \neq x \Rightarrow R(x, y) \lor R(y, x)] \\
\text{PSR} & & \text{Partitioned Strong Reciprocity} & \exists \Phi \subseteq \wp(A) [\bigcup \Phi = A] \land \forall P \in \Phi [\forall x, y \in P [y \neq x \Rightarrow R(x, y)]] \\
\text{SmR} & & \text{Symmetric Reciprocity} & \forall x \in A \exists y \in A [y \neq x \land R(x, y) \land R(y, x)] \\
\text{IR} & & \text{Intermediate Reciprocity} & \forall x, y \in A [y \neq x \Rightarrow R^*(x, y)]^1 \\
\text{PIR} & & \text{Partitioned Intermediate Reciprocity} & \exists \Phi \subseteq \wp(A) [\bigcup \Phi = A] \land \forall P \in \Phi [\forall x, y \in P [y \neq x \Rightarrow R^*(x, y)]] \\
\text{IAR} & & \text{Intermediate Alternative Reciprocity} & \forall x, y \in A [y \neq x \Rightarrow (R^?)^*(x, y)]^2 \\
\text{WR} & & \text{Weak Reciprocity} & \forall x \in A \exists y \in A [y \neq x \land R(x, y)] \\
\text{OWR} & & \text{One-way Weak Reciprocity} & \forall x \in A \exists y \in A [y \neq x \land R(x, y)]
\end{align*}

\[^1\text{We use the notation } R^* \text{ to denote the transitive closure of the binary relation } R. \]

\[^2\text{We use the notation } R^? \text{ to denote the symmetric closure of the binary relation } R. \]
IAO --- Inclusive Alternative Ordering

\[ \forall x \in A[\exists y \in A[y \neq x \land (R(x, y) \lor R(y, x))]] \]
Chapter 1

Introduction

One of the central problems in analyzing reciprocal expressions like *each other* stems from the fact that they do not seem to make a unitary logical contribution to sentences in which they appear. Consider for example the following sentences.

(1) Larry, Monty and Garfield know each other.
(2) Larry, Monty and Garfield are following each other into the room.

We will henceforth refer to such sentences containing reciprocal expressions as *reciprocal sentences*. The configurations in which Larry, Monty and Garfield may be knowing/following each other in these two sentences are not the same. While (1) requires that each of the three men knows the two other men, sentence (2) only requires a *linear* configuration, e.g. one in which Larry is entering the room first, with Monty following him and Garfield following Monty. In order to account for such variations in the interpretation of reciprocal sentences, Dalrymple et al. [4] catalogue the different meanings reciprocal expressions may receive and propose a principle called the *Strongest Meaning Hypothesis* (SMH) that selects between them. Reciprocal meanings are ordered according to their logical strength, where a stronger meaning requires more pairs in the binary relation denoted by the transitive predicate antecedent of the reciprocal. Thus, the reciprocal meaning in (1) is assumed to be stronger than the meaning in (2). The SMH in Dalrymple et al.’s formulation describes the interpretation of a reciprocal expression as the strongest available meaning that is not contradicted by the context. For instance, in (1) the context does not prevent each of the three men from knowing the other two. Hence the reciprocal is assigned the strongest meaning possible, requiring a
full graph of acquaintances. By contrast, in (2) it is impossible for each man to be following the other two into the room. Therefore a linear configuration is predicted by the SMH using one of the weaker reciprocal meanings that Dalrymple et al. assume.

Sabato and Winter [15] (henceforth S&W) adopt Dalrymple et al.’s general approach, but argue, following Winter [18], that it is first of all the meaning of the predicate antecedent of the reciprocal that determines its interpretation. S&W characterize logical parameters that derive directly from the meaning of binary predicates, and further revise the SMH for describing the effects of these parameters on the interpretation of the reciprocal.

**Strongest Meaning Hypothesis** (S&W’s version): *A reciprocal expression requires the denotation of the predicate in its scope to be a maximal relation that respects the semantic restrictions on the predicate concept.*

In (2) the relation denoted by the binary predicate *follow into the room* is restricted in the values it may receive (e.g. it must be acyclic) due to the meaning of the concept conveyed by this predicate. The predicate *know* in (1) involves no comparable restrictions. Thus, maximality in S&W’s version of the SMH requires a complete graph in (1) but a weaker interpretation in (2). These are reviewed in more detail in Chapter 2.

The two versions of the SMH by Dalrymple et al. and by S&W have a common property: they both assume that the interpretation of reciprocals is only sensitive to “classical” (or “definitional”) aspects of the meaning of relational concepts like *know* or *follow into the room*. For instance, the acyclicity of the latter relation can be treated as a non-logical axiom, or a meaning postulate, which holds true in all possible models. The implicit assumption is that the contextual effects (in Dalrymple et al.’s account) or the semantic properties of the predicate (in S&W’s account) that affect the interpretation of reciprocals are all of this sort.

This approach faces a general empirical problem, illustrated by sentence (3).

(3) Larry, Monty and Garfield are combing each other’s hair.

Sentence (3) allows the interpretation in which each of the three men is combing both the of the others’ hair, as depicted in Figure 1.1(a) below. However, unlike sentence (1), this interpretation is not the only one available for (3). For example, as supported by our empirical study (see Experiment 2 in Chapter 4), an interpretation in which each of the men only combs the hair of one of his companions, as
in Figure 1.1(b), is also felicitous for (3).

(a) Each man is combing both of the others' hair  
(b) Each man is combing one of the others' hair.

Figure 1.1: Two situations for the expression *combing each other*

According to the SMH, the physical possibility that each man combs the hair of the two other men blocks any weaker interpretation for (3), contrary to fact. Interpretations of reciprocal sentences that are weaker than expected by the SMH appear with many other transitive verbs (see Chapter 4). The central claim in this thesis is that this inadequacy of the SMH results from ignoring meaning properties of binary predicates that involve *typicality preferences* with natural concepts. With respect to sentence (3), for instance, we propose that the acceptability of the sentence as describing Figure 1.1(b) is related to the higher typicality of combing one person’s hair as a “combing situation” when compared to Figure 1.1(a).

Chapter 2 reviews previous work on the semantics of reciprocal expressions and on typicality in the theory of concepts. Chapter 3 introduces the MTH and its formalization. Chapter 4 surveys the empirical settings we used for testing the MTH and presents our experimental results and their analysis. Chapter 5 analyzes these results and their implication for the MTH. Chapter 6 concludes the thesis.
Chapter 2

Previous Works

In this thesis we suggest a new principle, the *Maximal Typicality Hypothesis* (MTH) for predicting the truth conditions of reciprocal sentences. The MTH extends proposals following the general approach that was first put forth by Dalrymple et al. [4], namely the Strongest Meaning Hypothesis. The extension we propose is rooted in the extensive body of research that has been done on the structure of the mental lexicon and takes *typicality preferences* into account in its formalization. In section 2.1 we survey the previous theories of reciprocal interpretation upon which this thesis is based. In section 2.2 we present the relevant background in the study of concepts and typicality preferences.

2.1 Reciprocal interpretation

2.1.1 Dalrymple et al. (1998)

Dalrymple et al. [4] (henceforth *DKKMP*) focus their study on reciprocal sentences with antecedent sets larger than two. According to DKKMP, a reciprocal expression is an indivisible syntactic unit, expressing a polyadic quantifier with a context-sensitive interpretation. They provide a two part system, wherein the first step enumerates the available reciprocal meanings and the second step chooses unambiguously from them.

*DKKMP* justify their course of investigation by first demonstrating how reliance on pragmatic strengthening (or weakening) of the reciprocal meaning, based on the speaker’s intention cannot account for the variance found in reciprocal interpretation. Consider the contrast between sentence (4) and sentences (5) and (6);
(4) John, George and Jacob were standing on each other; George was at the bottom, not standing on anybody.

(5) John, George and Jacob were staring at each other; # George had his eyes closed and was not staring at anybody.

(6) John, George and Jacob were listening each other; # George was distracted and did not listen anybody.

If the weaker reciprocal meaning of sentence (4) is due to a pragmatic mechanism, then we would have expected the same mechanism to allow sentences (5) and (6) to be equally felicitous, contrary to fact. Instead, the weaker meaning of (4) must result from an intrinsic part of the reciprocal’s conventional meaning, not from extra-semantic factors such as pragmatic weakening (or strengthening). It is under this premise that DKKMP propose their thesis.

DKKMP continue in cataloging the various meanings that have been proposed previously in the literature [primarily from 7]. They argue that the reciprocal acts as a polyadic quantifier, \( \text{RECIP}(A, R) \), that binds two variables in its scope; the antecedent set \( A \) and the binary relation \( R \). DKKMP attribute the differences in meaning that reciprocals receive to two parameters of variation in the behaviour of quantifier \( \text{RECIP} \):

The first parameter has to do with the scope in which the binary predicate \( R \) covers the domain \( A \). The possible values are:

1. Each pair of nonequal individuals in \( A \) participates in the relation \( R \) directly (FUL).
2. Each pair of nonequal individuals in \( A \) participates in the relation either directly or indirectly (LIN).
3. Each single individual in \( A \) participates in the relation \( R \) with some other, different individual (TOT)\(^1\).

The second parameter has to do with how the reciprocal’s scope determines the argument \( R \) of FUL, LIN or TOT. The possible values are:

1. The argument \( R \) of the quantifier is the relation denoted by the predicate in the reciprocal expression’s scope.

\(^1\)DKKMP use the notation \( FUL \setminus I \), \( LIN \setminus I \) and \( TOT \setminus I \) for what we here denote FUL, LIN and TOT respectively.
2. The argument $R$ of the quantifier is the symmetric closure of the relation denoted by the predicate in the reciprocal expression’s scope.\(^2\).

The different configurations these two values interact with one another results in $3 \times 2 = 6$ different quantifiers, each of them a possible reading for reciprocal expressions. For example, the weakest available reciprocal meaning in this system is called Inclusive Altering Ordering (or IAO\(^3\)) which is achieved with TOT as the first parameter and $R^\lor$ as the second. DKKMP contend that although more meanings beyond these six have been suggested in the literature (e.g. Weak Reciprocity, or WR\(^4\)), none of them have been univocally attested.

In the crux of DKKMP’s thesis is the mechanism regulating which of the available meanings a reciprocal expression gives rise to in a given sentence. The intuition being that the selected reciprocal meaning is the strongest meaning that is physically and logically possible given the context of the sentence. DKKMP name this principle the Strongest Meaning Hypothesis (henceforth the SMH) and define it thus:

**Strongest Meaning Hypothesis (as presented in Dalrymple et al.):** A reciprocal sentence $S$ can be used felicitously in a context $c$, which supplies non-linguistic information $I$ relevant to the reciprocal’s interpretation, provided the set $I_c$ has a member that entails every other one:

$$I_c = \{ p \mid p \text{ is consistent with } I \text{ and } p \text{ is an interpretation of } S \text{ obtained by interpreting the reciprocal as one of the six quantifiers [previously stated]} \}$$

In that case, the use of $S$ in $c$ expresses the logically strongest proposition in $I_c$.

Applying the SMH with the relevant contextual information on a given sentence chooses from the available reciprocal meanings and predicts the truth conditions for the interpretation of the reciprocal sentence. Consider sentence (2), restated here:

\[ (7) \quad \text{Larry, Monty and Garfield are following each other into the room.} \]

\(^2\)We henceforth use the notation $R^\lor$ to denote the symmetric closure of the binary predicate $R$.

Formally, $R^\lor \overset{\text{def}}{=} R \cup R^{-1}$

\(^3\)IAO requires that each member of the antecedent set $A$ participate either as the first or second argument in the binary predicate $R$.

IAO is formally defined as: $\forall x \in A[\exists y \in A[y \neq x \land (R(x, y) \lor R(y, x))]]$

\(^4\)WR requires that each member of the antecedent set $A$ participate both as the first argument and as the second argument in the binary relation $R$.

WR is formally defined as: $\forall x \in A[\exists y \in A[y \neq x \land R(x, y)] \land \exists y \in A[y \neq x \land R(y, x)]]$
This sentence entails that Larry, Monty and Garfield are walking in a line, one behind the other into the room; the meaning of the reciprocal expression in this case is called Intermediate Alternative Reciprocity (or IAR\(^5\)). The predicate follow into a room denotes an asymmetric relation in which each child may follow and may be followed by at most one other child. Furthermore, there must be one person in the room first, i.e. not following anybody else, and one person in the room last, with no one following him. Of the six meanings, IAR is indeed the strongest meaning available within these constraints. Thus, the SMH correctly predicts the reciprocal interpretation of sentence (7). Contrast the interpretation of sentence (7) with that of sentence (1), restated here:

(8) Larry, Monty and Garfield know each other.

This sentence entails that each of the three men knows the other two; the reciprocal expression receives Strong Reciprocal meaning (or SR\(^6\)). In this case, as opposed to (7), the context of the sentence contains no restrictions on the possible configuration of Larry, Monty and Garfield with know relations, and the SMH selects SR, strongest meaning available for the reciprocal expression.

In some cases DKKMP’s system fails to predict the correct reciprocal meaning. One such case is sentence (9), taken from J.M. Barrie’s Peter Pan, quoted in DKKMP:

(9) “The captain!” said the pirates, staring at each other in surprise.

As DKKMP themselves observe, the meaning of the reciprocal expression in this sentence matches One-way Weak Reciprocity (or OWR\(^7\)), whereby each pirate stares at some other pirate. Despite this, nothing in the context of the sentence disallows a stronger meaning, namely Intermediate Reciprocity (or IR\(^8\)). Such an interpretation is possible if, for example, the pirates were to stand in a circle, each

---

\(^5\)IAR requires that each member of the antecedent set \(A\) participate as the first or the second argument in the transitive closure of the binary predicate \(R\) with every other member of \(A\). IAR is formally defined as \(\forall x, y \in A [y \neq x \Rightarrow (R^\ast)^{(2)}(x, y)]\).

\(^6\)SR requires that each member of the antecedent set \(A\) participate both as the first and as the second argument of the binary relation \(R\) with every other member of \(A\). SR is formally defined as: \(\forall x, y \in A [y \neq x \Rightarrow R(x, y)]\).

\(^7\)OWR requires that each member of the antecedent set \(A\) participate as the first argument in the binary relation \(R\). OWR is formally defined as: \(\forall x \in A [\exists y \in A [y \neq x \land R(x, y)]]\).

\(^8\)IR requires that each member of the antecedent set \(A\) participate both as the first and the second argument in the transitive closure of the binary predicate \(R\) with every other member of \(A\). IR is formally defined as: \(\forall x, y \in A [y \neq x \Rightarrow R^\ast(x, y)]\).
one staring at the pirate to his right. In such a situation, each pirate both stares at another pirate and is stared at by some pirate; an interpretation consistent with IR. DKKMP provide no explanation for the weaker reciprocal meaning of sentence (9).

2.1.2 Sabato and Winter (2005)

Sabato and Winter [15] (henceforth S&W) adopt the assumptions of DKKMP regarding the role of the reciprocal expression as a syntactic unit expressing a polyadic quantifier, and building upon the intuitions laid out in DKKMP, propose a different formal system for describing the SMH.

As opposed to DKKMP’s version of the SMH, in which the meaning of the reciprocal expression is selected from a set of available meanings, S&W propose an alternate approach, devoid of apriori assumptions on an independent mechanism for first producing the available meanings, that employs fewer assumptions and creates better predictions on the truth conditions of reciprocal interpretations. In this system, the SMH is realized directly from the lexical properties of the reciprocal expression and the binary predicate in its scope.

S&W define the notion of semantic restrictions as the set of relations that are possible as denotations of a predicate. According to S&W, a semantic restriction of a binary predicate \( P \) over the domain of entities \( E \) is the set \( \Theta^cl_P \subseteq \wp(\wp(E^2)) \). For example, for the predicate \( \text{stare at} \), one person cannot stare at more than one other person at a time, therefore \( \Theta^cl_{\text{stare at}} \) is limited to the set of (possibly partial) functions.

On the other hand, the predicate \( \text{like} \) presents no such limitations on its available denotations, being as there is no definitional limit on the number of people one may like, or on the number of people that may like some specific person. Hence in this case \( \Theta^cl_{\text{like}} = \wp(\wp(E^2)) \).

In a given reciprocal sentence \( S \) with semantic restrictions \( \Theta^cl \) of the predicate in the scope of the reciprocal expression, obviously the predicate can only denote relations within \( \Theta^cl \). Therefore S&W define the interpretation \( \mathcal{I}_{\Theta^cl} \) for the reciprocal expression in \( S \) only for relations that are within the semantic restrictions of the predicate in the scope of the reciprocal expression. Thus, the interpretation of the reciprocal expression in \( S \) is defined \( \mathcal{I}_{\Theta^cl} \subseteq \wp(E) \times \Theta^cl \) while the reciprocal interpretation domain \( \text{RECIP}_{\Theta^cl} \) of the semantic restriction \( \Theta^cl \) is defined \( \text{RECIP}_{\Theta^cl} \overset{\text{def}}{=} \wp(\wp(E) \times \Theta^cl) \).

---

\(^9\)S&W use the notation \( \Theta_P \) to denote the semantic restrictions of binary predicate \( P \)
Employing this framework, the Strongest Meaning Hypothesis may be reconceived in a more explicit and compact formulation than the one originally proposed by DKKMP. S&W define the operation of the SMH by analyzing the reciprocal expression as requiring that the predicate in its scope denotes a local maximal relation on the set denotation of the subject, relative to the verb’s semantic restrictions. In sentence (7), for instance, given the acyclicity and asymmetry of the verb follow, a linear configuration on the three elements of the subject describes a maximal relation for this set: adding any pair to this relation would stand in contradiction to the properties of the predicate concept. In sentence (8) the predicate know poses no acyclic or any other restriction on its denotation and Θ_{cl}^know = φ(E^2), therefore the maximal relation available is the complete graph, in which each of the three men knows both of the others.

More formally, for any domain of entities E, a reciprocal expression in S&W’s proposal denotes a relation that holds of the sets A ⊆ E and binary relations R ⊆ E^2, where R is locally maximal on A relative to the semantic restriction Θ^cl on the predicate concept (e.g. KNOW, FOLLOW). Maximality of R on A is defined by examining the relation R|_A = R ∩ A^2. Pairs of binary relations R_1, R_2 should be compared while restricting them to the set A and ignoring identity pairs on A: the pairs I_A = {⟨x, x⟩ ∈ E^2 : x ∈ A}. The proper equality (‘= _A’) and containment (‘⊆ _A’) relations are defined as follows.

\[ R_1 =_A R_2 \iff R_1|_A \setminus I_A = R_2|_A \setminus I_A \]

\[ R_1 \subseteq_A R_2 \iff R_1|_A \setminus I_A \subseteq R_2|_A \setminus I_A \]

Informally: when comparing two binary relations R_1 and R_2 on a set A, we only look at the pairs of elements that they relate within A that are not identity pairs. Ignoring identity pairs is necessary because the meaning of reciprocals is contingent with respect to membership of such pairs in the denotation of the reciprocated binary relation. For instance, the truth of a sentence like John and Bill admire each other does not depend on whether John (or Bill) admires himself or not.

With these tools at hand we may now redefine the SMH as proposed in S&W:

**Strongest Meaning Hypothesis (according to Sabato and Winter):** Let Θ^cl be a semantic restriction over E. An SMH-based interpretation of a reciprocal expression is a relation R_{Θ^cl} ∈ RECIP_{Θ^cl} such that R_{Θ^cl} is a local maximal relation within Θ^cl. Formally:
∀A ⊆ E, R ∈ Θ \([R_{\text{cl}}(A, R) \iff \forall R' \in Θ \[(R \subseteq A R') \Rightarrow (R = A R')]]\)

This new realization of the SMH makes correct predictions in some cases where the original account laid out by DKKMP failed. Consider sentence (9) from the previous section. As stated above, the semantic restriction of Θ_{\text{stare at}} contain only (possibly partial) functions over E. Thus, an SMH-based interpretation of sentence (9) is one in which every pirate is staring at some other pirate. In such interpretations, no more relations may be added without having some pirate stare at more than one other pirate. Obviously, no such relations exist in Θ_{\text{stare at}}. This gives the expected interpretation of this sentence, one consistent with OWR. This case exemplifies that the weaker requirement of a local maximum in the system proposed by S&W, as opposed to the global maximum required in DKKMP’s system captures the truth conditions of reciprocal sentences more precisely.

Despite the progress in predicting reciprocal interpretation, the SMH as presented by S&W is still falls short of providing a complete account of reciprocal behaviour, creating incorrect predictions of reciprocal interpretation in some cases. Consider sentence (3), presented again below:

(10) Larry, Monty and Garfield are combing each other’s hair.

The semantic restrictions of Θ_{\text{comb}} contain only relations in which each element participates at most in two relations as the first argument, being as people may only hold two combs simultaneously. This leads to the prediction that an SMH-based interpretation of sentence (10) is one in which each of the three men is combing both of the others. As we show in Chapter 4, this prediction is too strong, and weaker interpretations are accepted for sentence (10), for instance, the situation depicted in Figure 1.1(b) in which each of the three men is only combing one of the other men is felicitous with the sentence.

### 2.2 Concepts and typicality

Ordinary concepts like FRUIT or BIRD have been the center of much research in Cognitive Psychology, Philosophy, and Linguistics. Many works (see [8], [16] for reviews) have studied the processes in which humans categorize objects as instances of concepts, and have developed theories about how these concepts may be represented in the human mind. According to the classical theory of concepts, their representation has a definitional structure expressing the necessary and sufficient conditions for categorizing entities as instances of the concept. A popular
example is the concept BACHELOR, which may be defined as the conjunction of the concepts UNMARRIED and MAN. The classical theory assumes that such “definitional” reductions can ultimately describe the mental structure of concepts, as well as their use for categorization.

Despite its influence on the theory of concepts, the classical theory suffers from essential shortcomings. An influential argument challenging the classical theory stems from empirical evidence often called typicality effects. Typicality effects refer to empirical findings which indicate that not all items in a category are of equal stature within that category, rather they are on a continuum of concept “representativeness”. A well-known example involves categorizing instances of the category BIRD. Instances of birds like robins or sparrows were shown to rate as “better” or “more typical” examples of the concept BIRD than other bird instances like chickens, penguins or ostriches. Instances of the former species are categorized more quickly as birds, acquired earlier in childhood, and listed more often as examples for birds. Some of the categorization tasks that were shown to exhibit such typicality effects include category membership [e.g. 11], sentence verification [e.g. 2] and inductive inference [e.g. 9], as well as acceptance of qualifying terms [e.g. 6], memory encoding and recall [e.g. 12, 13], category learning [e.g. 12, 13] and many other tasks.

Furthermore, typicality effects have been shown to exist in many different concept types, form simple objects such as BIRD and CHAIR [11], to mathematical and geometric categories such as ODD NUMBER or TRIANGLE [2], traits and emotions such as DOMINANT [3], FEMALE [2] or LOVE [5], even algorithms such as SORTING or SEARCHING [1] and so forth.

Researchers have used various terms to signify the quality that concepts possess which may account for the varying typicality preferences that a concept may have for different members of the category; ‘typicality’, ‘representativeness’, ‘exemplar goodness’, ‘prototypicality’, ‘graded structure’, ‘goodness of exemplification’ etc. In this thesis we will be using the term typicality.

The large body of research and the correlations it has exposed between typicality effects in different categorization tasks have led to the conclusion that any theory of concepts must take typicality into account. The classical theory, whatever its status as a theory of concepts may be, has no natural model that can explain this phenomenon because at its core it assumes a binary decision of either belonging or not belonging to the concept. It therefore takes all instances of a concept as equal members of the category. Thus classical models of categorization do not predict
any sort of typicality preferences and attempts to accommodate for them quickly run into further problems.

In formalizing typicality, we use Osherson and Smith’s (1997) notation, where typicality of entities with respect to a concept CON is described by a typicality function $\Theta_{CON}$ that assigns entities values in the interval $[0, 1)$ – the non-negative real numbers smaller than 1.\footnote{The reason for not allowing typicality 1 is Osherson and Smith’s assumption that no entity is maximally typical as an instance of a concept. Osherson and Smith use the notation ‘$c^p$’ for the function that we here denote ‘$\Theta_{CON}$’.} Elements that are more typical of the concept receive a higher score. For instance, in the above example we assume $\Theta_{BIRD}(r') > \Theta_{BIRD}(p')$, where $r'$ and $p'$ are instances of a robin and a penguin respectively.
Chapter 3

The Maximal Typicality Hypothesis

This chapter revises and generalizes the SMH, and proposes a modified principle, the Maximal Typicality Hypothesis (MTH), for generating the truth conditions of reciprocal sentences. Instead of only considering the possibility or impossibility of different denotations for binary predicates, as in the SMH, the MTH also takes into account the typicality of different denotations. Revising S&W’s formulation, we informally state the MTH as follows.

Maximal Typicality Hypothesis (MTH): A reciprocal expression requires the denotation of the predicate in its scope to be a relation of maximal typicality relative to the predicate concept.

Intuitively, the idea is that when three people are involved, situations as in Figure 1.1(b), with each person combing only one other person, are maximally typical for the concept COMB, and hence licensed as situations of reciprocal combing for sentence (10). This is an extension of Dalrymple et al.’s intuition that the linear configuration of people following each other in sentence (7) is a maximal situation for the concept FOLLOW INTO THE ROOM. In the first case, adding pairs to the relation is possible, but atypical; in the latter case, adding pairs to the relation is strictly speaking impossible. The MTH thus takes the two cases of “incomplete” reciprocity as stemming from the same principles of conceptual structure.

The MTH assumes that similarly to other concepts, concepts underlying binary predicates show typicality preferences between different instances of the predicate. But what is an “instance of the predicate”? With one-place predicate concepts like
BIRD, an instance is standardly assumed to be an entity categorized as belonging to the predicate extension. With concepts corresponding to transitive verbs, however, an instance must involve at least two entities, denoted by the subject and the object. Furthermore, we are here also interested in typicality of situations with three or more entities. Consider for example the two situations in Figure 3.1. The (b) situation is an instance of the predicate *comb* that only involves one patient.\(^1\) The (a) situation, however, involves one agent and two patients. To rank the typicality of the two situations as *combing* exemplars, we assume that it is the denotation of a two-place predicate *comb*, restricted to the entities in the situation, that is ranked for typicality. If we standardly assume that transitive verbs like *comb* denote binary relations, the underlying concept COMB must attribute typicality to different binary relations. In Figure 3.1, let \(x, y, z\) denote the participating entities. In the (a) situation the restricted denotation of the verb *comb* is the relation \(R_a = \{(x, y), (x, z)\}\), whereas in (b) it is the relation \(R_b = \{(x, y)\}\). As for the typicality of these relations with respect to the verb concept, we adopt (and later empirically support) the assumption \(\Theta_{\text{COMB}}(R_a) < \Theta_{\text{COMB}}(R_b)\).

\[\text{(a) Two patients} \quad \text{(b) One patient}\]

**Figure 3.1:** Combing with one or two patients

Thus, typicality of binary relations as instances of a concept CON is described using a function \(\Theta_{\text{CON}}\) from binary relations over the domain, i.e. elements of

\(^1\)In some of the verbs that we discuss below, the thematic role of the object is not a patient, but a theme. We ignore however this thematic distinction, and consistently use the terms *agent* and *patient* for referring to the entity or entities denoted by the subject or the object, respectively.
\(\varphi(E^2)\), to typicality values in the interval \([0, 1]\). The MTH uses such typicality functions for defining the interpretation of reciprocals. Consider first the semantic structure of sentences like \textit{the boys know each other} (= (8)). The reciprocal expression is analyzed as a relation between sets of entities and binary relations over entities. Accordingly, sentence (8) is analyzed as stating that the reciprocal relation holds between the set of boys and the binary relation denoted by the verb \textit{know}.

To see how the proposed MTH works, let us first consider S&W’s proposal, which the MTH generalizes. According to S&W the meaning of a reciprocal expression is defined relative to a \textit{semantic restriction} describing the possible binary relations instantiating the predicate concept. For instance, in the case of sentence (7) above, which we discussed in Chapter 2 we saw that the possible instances of the concept related to the expression \textit{follow into the room} must all be acyclic, asymmetric relations. We will denote by \(\Theta_{\text{FOLLOW}}^cl\) such a “classical” semantic restriction, which sends any binary relation to 1 if it is acyclic and asymmetric, and to 0 otherwise. Our notation here is meant to highlight our conviction that Dalrymple et al.’s assumption about contextual effects and S&W’s assumption about semantic restrictions should be construed as manifestations of the conceptual structure of two-place predicates, which is more accurately reflected, and formally generalized, using typicality functions.\(^2\)

Using this notion for semantic restrictions, the definition below applies the SMH according to S&W for specifying the meaning of reciprocal relations.\(^3\)

**SMH-based reciprocity:** Given a semantic restriction \(\Theta^{cl} : \varphi(E^2) \rightarrow \{0, 1\}\), a set of entities \(A \subseteq E\) and a binary relation \(R \subseteq E^2\) s.t. \(\Theta^{cl}(R|A) = 1\) exhibit reciprocality with respect to \(\Theta^{cl}\) if and only if the following holds:

\[
\forall R' \subseteq E^2: R \subseteq_A R' \land \Theta^{cl}(R|A) \leq \Theta^{cl}(R'|A) \Rightarrow R =_A R'.
\]

It is easy to illustrate that under this formulation a reciprocal relation must hold between a set \(\{x, y, z\}\) and a linear relation \(\text{follow}' = \{\langle x, y\rangle, \langle y, z\rangle\}\), provided that the semantic restriction \(\Theta_{\text{FOLLOW}}^{cl}\) contains all and only the acyclic asymmetric binary relations over the domain. By contrast, we can assume that the semantic restric-

\(^2\)Notice that the formal definition presented here is equivalent to S&W’s definition of semantic restrictions presented in page 13, whereby a relation \(R\) is in the semantic restriction set in S&W’s definition iff \(R\) is mapped to 1 in our definition.

\(^3\)Our formulation of S&W’s proposal contains here a slight redundancy: due to the assumption \(\Theta^{cl}(R|A) = 1\), the requirement \(\Theta^{cl}(R|A) \leq \Theta^{cl}(R'|A)\) boils down to requiring \(\Theta^{cl}(R'|A) = 1\). This redundancy only comes to highlight the generalization embodied in our definition of the MTH below.
tion $\Theta_{\text{know}}^{cl}$ allows all possible relations in the domain, since there is no *a priori* restriction on who knows who. Unlike *follow*, the reciprocal relation would not hold for linear relations denoted by *know*, as these are not maximal relative to the semantic restriction $\Theta_{\text{know}}^{cl}$. This analysis captures the contrast between sentences (7) and (8).

The idea behind the MTH is similar to S&W’s formulation of the SMH, but it takes typicality of binary relations as the core semantic information on binary predicate concepts, rather than “classical” semantic restrictions on their meaning. Reconsider the two situations in Figure 1.1. While Figure 1.1(b) does not contain a maximal number of possible pairs in the denotation of the predicate *comb*, we assume that it is a situation of maximal typicality for the concept. Thus, adding more pairs is possible (see Figure 1.1(a)), but doing this might result in a situation that is less typical of the concept *COMB*. We hypothesize that this is the reason for the acceptability of the reciprocal sentence (10) in Figure 1.1(b), contrary to what the SMH expects. Revising the formulation of the SMH based on S&W’s work, using this notion of maximal typicality, we propose the following MTH-based definition.

**MTH-based reciprocity:** Given a typicality function $\Theta : \wp(E^2) \to [0, 1)$, a set of entities $A \subseteq E$ and a binary relation $R \subseteq E^2$ s.t. $\Theta(R|_A) > 0$ exhibit reciprocity with respect to $\Theta$ if and only if the following holds:

$$\forall R' \subseteq E^2 : R \subseteq_A R' \land \Theta(R|_A) \leq \Theta(R'|_A) \Rightarrow R =_A R'.$$

Thus, according to the MTH, if for all pairs $\langle a_1, a_2 \rangle$ of non-equal elements $a_1 \neq a_2$ in $A$, adding $\langle a_1, a_2 \rangle$ to $R$ reduces $R$’s typicality on $A$, then $A$ and $R$ are said to stand in the reciprocity relation. In the two situations of Figure 1.1, let us denote the relevant combing relations $R_a'$ and $R_b'$ respectively. We assume that the typicality $\Theta_{\text{comb}}(R_b')$ is higher than the typicality of any situation where a combing action is added to $R_b'$. If this is the case, then the MTH correctly expects $R_b'$ to exhibit reciprocity with respect to the three people in the situation. Note that according to the MTH, the complete relation $R_a'$ also exhibits reciprocity with respect to these three people. This is since, provided that the typicality of $R_a'$ is larger than zero, it is maximally typical in the sense of the MTH: adding non-identity pairs to the situation is impossible, and hence trivially cannot reduce its typicality. Even more generally, adding any pair to the three pairs in situation (b) is expected to monotonically reduce the typicality of the situation for the concept *COMB*. Under this assumption, any of the situations with 4, 5 and 6 combing pairs is expected by
the MTH to exhibit reciprocity, as we believe is the case.

Since the MTH is strictly speaking an extension of S&W’s formalization of the SMH, it also extends its results, after moving from “classical” semantic restrictions to more general typicality functions. Specifically, the contrast between the predicates follow and know in sentences (7) and (8) is accounted for in a similar way to S&W’s account. For the predicate know, we may reasonably assume that typicality increases monotonically or remains constant when adding more pairs to the relation. According to this assumption, only a maximal knowing relation, including all possible non-identity pairs, supports sentence (8) according to the MTH. Further, S&W’s assumption that all and only acyclic and asymmetric relations are possible denotations for the predicate follow can be described using a typicality function that sends only such relations to a positive value, whereas cyclic and/or asymmetric relations are assigned typicality zero. With this assumption on typicality for follow, we may again assume that typicality grows monotonically or remains constant when adding pairs to a relation within the set of acyclic asymmetric relations. This accounts for the contrast with the predicate know: adding any pair to a linear configuration would reduce its typicality to zero, whereas taking pairs out of such a configuration would reduce its typicality, or leave it intact. Consequently, according to the MTH, a linear configuration exhibits reciprocity for the predicate follow but not for the predicate know.

Concluding, the MTH encodes the lexical semantic assumptions of the SMH as typicality functions and preserves some desired empirical aspects of S&W’s system. However, because the MTH is a more general principle than the SMH, it is used to account for phenomena that cannot be captured using the classical theory of concepts. In the remainder of this paper, we turn to a preliminary experimental study of the implications of the MTH.
Chapter 4

Experimental Support for the Maximal Typicality Hypothesis

The MTH establishes a relation between typicality effects with binary predicates and the interpretation of reciprocal expressions appearing with them. For instance, when comparing Figures 1.1(a) and 1.1(b), the MTH assumes that it is the higher typicality of the latter as an instance of the concept COMB, which licenses reciprocity in it. Reasonably, the main factor that makes Figure 1.1(a) an atypical instance of the concept is the fact that each of the persons in it is the agent, as well as the patient, of two combing activities. Thus, in Figure 3.1 we expect the typicality of the (b) situation, with one patient, to be higher than the typicality of the (a) situation, where two patients are combed simultaneously by the same agent. Typicality preferences with such “one agent” situations are assumed to reflect the basic conceptual structure of verbs, and to correlate with the typicality of the more complex situations of Figure 1.1. In the four experiments that we describe below, we make the tentative experimental assumption that typicality preferences in “one agent” situations are indicative of typicality of situations with more agents (and patients). It follows that we expect typicality judgements about patient cardinality in situations like Figures 3.1(a) and 3.1(b) to correlate with reciprocity judgements about situations like Figures 1.1(a) and 1.1(b) respectively. This expectation was tested in two pairs of experiments presenting situations that were examined for their typicality and reciprocity relative to sentences of natural language. In Experiments 1 and 2 the situations were presented graphically, and in Experiments 3 and 4, they were presented textually. All tests were performed on native speakers of
Modern Hebrew, university students from Tel Aviv University and Technion, Israel Institute of Technology.

4.1 Experiment 1 – Preferences of patient cardinality (picture-based)

This experiment tested typicality preferences with binary predicates in Hebrew using picture selection in depicted situations that differ in their patient cardinality.

Method 53 participants (39 male and 14 female, average age 24) were given a form containing 38 questions, of which 32 were test items and 6 fillers. Each test item covered one binary concept, and was designed to compare the typicality judgements on two instances of this concept. These instances were illustrated in two drawings, where one agent performs the relevant activity on one patient or on two patients. Apart from the number of patients the two drawings were as similar as possible. In addition to these two drawings, each test item contained a sentence, and the typicality judgement was elicited by introducing to the participants a forced choice question: which of the two depicted situations better describes the sentence? In all items, the subject of the sentence was visibly the agent in the drawings, and the verb corresponding to the binary concept in question appeared without an object. For example, for the binary predicate concept HIT, the two drawings in Figure 4.1 were presented together with sentence (11)

(11) ha-yeled make
the-boy hits
“The boy is hitting.”

Filler items contained two pictures that differed from one another in respects other than patient cardinality (e.g location or instrument). In order to cancel out priming effects, the questionnaire forms had two versions in opposite orders of the items. In both versions of the questionnaire, if the same verb served both for a filler and in a test item, then the test item came before the filler.

Results Different verbs showed different preferences for the cardinality of objects. Some verbs (such as ‘stab’, ‘shake’ and ‘comb’) showed a clear preference for a single object, whereas other verbs (e.g. ‘give a speech’ and ‘take a picture’)

24
showed a preference for multiple objects. Yet other verbs showed no significant preference, with choices not significantly different from random (‘catch’ or ‘blind’, for example). Table 4.1 shows the verbs tested and for each verb, the percentage of participants who preferred the picture depicting one patient over the picture with two patients.

<table>
<thead>
<tr>
<th>Verb</th>
<th>Translation</th>
<th>Percent of participants preferring the single patient picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>no’em</td>
<td>‘give a speech’</td>
<td>7.5</td>
</tr>
<tr>
<td>mecalem</td>
<td>‘photograph’</td>
<td>24.5</td>
</tr>
<tr>
<td>mecayer</td>
<td>‘draw’</td>
<td>26.4</td>
</tr>
<tr>
<td>mexabek</td>
<td>‘hug’</td>
<td>32.1</td>
</tr>
<tr>
<td>mena’ane’a</td>
<td>‘rock / lull’</td>
<td>38.5</td>
</tr>
<tr>
<td>medaber</td>
<td>‘talk to’</td>
<td>41.5</td>
</tr>
<tr>
<td>Sotef</td>
<td>‘wash’</td>
<td>41.5</td>
</tr>
<tr>
<td>masm’i’a</td>
<td>‘play [sound]’</td>
<td>42.0</td>
</tr>
<tr>
<td>mefasel</td>
<td>‘sculpt’</td>
<td>43.4</td>
</tr>
<tr>
<td>mesanver</td>
<td>‘dazzle’</td>
<td>50.0</td>
</tr>
<tr>
<td>roxec</td>
<td>‘bathe’</td>
<td>50.0</td>
</tr>
<tr>
<td>tofes</td>
<td>‘catch’</td>
<td>51.9</td>
</tr>
<tr>
<td>melatef</td>
<td>‘caress’</td>
<td>53.8</td>
</tr>
<tr>
<td>martiv</td>
<td>‘wet’</td>
<td>56.6</td>
</tr>
<tr>
<td>doxef</td>
<td>‘push’</td>
<td>58.5</td>
</tr>
<tr>
<td>mesaben</td>
<td>‘soap’</td>
<td>61.5</td>
</tr>
</tbody>
</table>

Figure 4.1: Hitting with one or two patients
Table 4.1: Patient cardinality preference in Experiment 1

<table>
<thead>
<tr>
<th>Verb</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>medagdeg</td>
<td>‘tickle’</td>
</tr>
<tr>
<td>maSpric</td>
<td>‘spray’</td>
</tr>
<tr>
<td>cove’a</td>
<td>‘paint’</td>
</tr>
<tr>
<td>soret</td>
<td>‘scrape’</td>
</tr>
<tr>
<td>menake</td>
<td>‘clean’</td>
</tr>
<tr>
<td>me’aper</td>
<td>‘apply makeup’</td>
</tr>
<tr>
<td>noge’a</td>
<td>‘touch’</td>
</tr>
<tr>
<td>yore</td>
<td>‘shoot’</td>
</tr>
<tr>
<td>covet</td>
<td>‘pinch’</td>
</tr>
<tr>
<td>mesarek</td>
<td>‘comb’</td>
</tr>
<tr>
<td>menagev</td>
<td>‘towel’</td>
</tr>
<tr>
<td>macbi’a</td>
<td>‘point at’</td>
</tr>
<tr>
<td>make</td>
<td>‘hit’</td>
</tr>
<tr>
<td>mena’er</td>
<td>‘shake’</td>
</tr>
<tr>
<td>doker</td>
<td>‘stab’</td>
</tr>
</tbody>
</table>

4.2 Experiment 2 – Preferences of reciprocal interpretations (picture-based)

Experiment 2 tested acceptance of reciprocal interpretations of sentences containing a subset of the verbs used in Experiment 1. The verbs chosen for this experiment were the verbs that showed highest or lowest preferences for a single patient in Experiment 1, and that most easily allowed graphical representation of the relevant reciprocal situations.

Method Experiment 2 was set up similarly to Experiment 1. 50 participants (30 male and 20 female, average age 25) were given a form consisting of 49 questions: 26 test items and 23 fillers. Each test item contained two drawings and a reciprocal sentence with a subject referring to three people. The two pictures were as similar as possible, each depicting three people acting on each other in a different constellation. As in Experiment 1, the participants were asked to choose which of the two
pictures better describes the sentence. For each verb, the questionnaire included two test items. In one test item for the verb, one of the pictures depicted six pairs of activities between the human figures (i.e. every figure acting on each of the two other figures), and the other picture depicted three pairs (each figure acting on the figure to its right). In the two pictures of the other test item for the verb, one picture depicted three pairs identically to the first test item, and the other picture depicted two pairs of activities, where the agents in the two pairs were two different figures. The reciprocity judgement was elicited by asking the participants a forced choice question: which of the two depicted situations better describes the sentence? For example, for the binary predicate concept COMB, the two test cases consisted of Figure 1.1 and Figure 4.2, and the following reciprocal sentence:

(12) danny, gai ve’omer mesarkim ze-et-ze
    Danny, Guy and-Omer comb each other
    “Danny, Guy and Omer are combing each other.”

The filler items presented non-reciprocal sentences and pictures.

![Two situations for the expression combing each other](image)

(a) Only two men are combing the hair of another man
(b) Each man is combing one of the others’ hair

**Figure 4.2:** Two situations for the expression *combing each other*

**Results** Table 4.2 shows the verbs tested and, for each verb, the percentage of participants who preferred the three-pair picture to the six-pair picture, as well as the percentage preferring the two-pair picture to the three-pair picture.
Table 4.2: Reciprocal interpretation preference in Experiment 2

<table>
<thead>
<tr>
<th>Verb</th>
<th>Translation</th>
<th>Participants’ preferred picture (in percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3 pairs over 6</td>
</tr>
<tr>
<td>mexabek</td>
<td>‘hug’</td>
<td>10.0</td>
</tr>
<tr>
<td>make</td>
<td>‘hit’</td>
<td>18.4</td>
</tr>
<tr>
<td>covea</td>
<td>‘paint’</td>
<td>24.0</td>
</tr>
<tr>
<td>macbi’a</td>
<td>‘point at’</td>
<td>28.6</td>
</tr>
<tr>
<td>covet</td>
<td>‘pinch’</td>
<td>34.0</td>
</tr>
<tr>
<td>mena’er</td>
<td>‘shake’</td>
<td>34.0</td>
</tr>
<tr>
<td>doker</td>
<td>‘stab’</td>
<td>38.0</td>
</tr>
<tr>
<td>menake</td>
<td>‘clean’</td>
<td>40.0</td>
</tr>
<tr>
<td>menagev</td>
<td>‘towel’</td>
<td>40.0</td>
</tr>
<tr>
<td>me’aper</td>
<td>‘apply makeup’</td>
<td>40.0</td>
</tr>
<tr>
<td>soret</td>
<td>‘scrape’</td>
<td>42.0</td>
</tr>
<tr>
<td>no’em</td>
<td>‘give a speech’</td>
<td>42.0</td>
</tr>
<tr>
<td>mesarek</td>
<td>‘comb’</td>
<td>65.3</td>
</tr>
</tbody>
</table>

From these results we see that verbs like ‘comb’, which show a preference for a single patient, do not require complete configurations for reciprocal sentences in which they appear. By contrast, all verbs, independently on their preferences for patient cardinality, strongly prefer configurations with 3 pairs to 2 pairs as situations supporting reciprocal sentences.

4.3 Experiment 3 – Preferences of patient cardinality (text-based)

Similarly to Experiment 1, Experiment 3 tested typicality preferences with binary predicates in Hebrew using elicited judgements on situations that differ in their patient cardinality. Unlike Experiment 1, here the situations were verbally described, and in each test item the participants were asked to choose between a singular object a plural object in a transitive sentence illustrating the concept in question.
Method  50 (41 male and 9 female, average age 25) participants were given a form containing 28 questions: 18 test items and 10 fillers. Each test item consisted of an incomplete transitive sentence in which the object was missing. The incomplete sentence was accompanied by two possible objects, one singular and one plural. Participants were asked to choose which of the two objects completed the sentence in a way that sounds best to them. In this textual experiment, unlike the graphical Experiment 1, it was experimentally easier to use verbs for referring to activities in the past. We hypothesize that the aspect of the activity, especially whether it was completed (perfective aspect) or not (imperfective aspect), may affect the typicality of the activity. Eventive verbs like ‘to compliment’ were tested in both the perfective and the imperfective. Stative verbs like ‘hate’, were only tested in the perfective aspect. When two test items contained the same verb, at least three other test items separated between them. Modern Hebrew lacks overt aspectual marking, and the aspect (perfective/imperfective) of the activity was highlighted using the tense of the sentence (past/present, respectively) and the use of report verbs with the imperfective. Sentences (13) and (14) illustrate the test items in the perfective and imperfective aspect, respectively, for the verb *hexmi* (‘compliment’).

(13) ba-Sana Se’avra omer hexmi ... a. la-yalda  b. la-yeladot
in-the-year that-passed Omer complimented ... a. to-the-girl  b. to-the-girls

“Last year Omer complimented ... a. the girl  b. the girls”

(14) Rina nixnesa ve-hivxina be’omer maxmi ... a. la-yalda  b. la-yeladot
Rina entered and-noticed in-Omer compliment ... a. to-the-girl  b. to-the-girls

“Rina entered and noticed Omer complimenting ... a. the girl  b. the girls”

The filler items contained objects that differed from one another in respects other than patient cardinality (e.g. gender).

Results  Table 4.3 shows for each verb, in its possible aspects, the percentage of participants who preferred the singular object to the plural object.
<table>
<thead>
<tr>
<th>Verb</th>
<th>Translation</th>
<th>Percent of participants preferring the singular object sentence completion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Perfective</td>
</tr>
<tr>
<td>no’em</td>
<td>‘give a speech’</td>
<td>10.4</td>
</tr>
<tr>
<td>ro’e</td>
<td>‘see’</td>
<td>25.0</td>
</tr>
<tr>
<td>makSiv</td>
<td>‘listen to’</td>
<td>42.9</td>
</tr>
<tr>
<td>maxmi</td>
<td>‘compliment’</td>
<td>62.0</td>
</tr>
<tr>
<td>machia</td>
<td>‘point at’</td>
<td>81.3</td>
</tr>
<tr>
<td>soret</td>
<td>‘scrape’</td>
<td>93.8</td>
</tr>
<tr>
<td>doker</td>
<td>‘stab’</td>
<td>95.8</td>
</tr>
<tr>
<td>mefake’ax</td>
<td>‘supervise’</td>
<td>18.0</td>
</tr>
<tr>
<td>somex al</td>
<td>‘trust’</td>
<td></td>
</tr>
<tr>
<td>sone</td>
<td>‘hate’</td>
<td></td>
</tr>
<tr>
<td>Soxe’ax</td>
<td>‘forget’</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3: Preference for singular objects in Experiment 3

4.4 Experiment 4 – Preferences of reciprocal interpretations (text-based)

Method 103 participants (76 male and 27 female, average age 24) received one of two forms, which together contained 69 questions. Of the 69 questions, 16 were test items and 53 were fillers. In each test item participants were presented with a reciprocal sentence containing a subject referring to three people. The participants were asked whether it is necessary or not to conclude from the given sentence that one person of those referred to acted on another one (both persons were given by name). The verbs tested were the same ones as in Experiment 3. As in Experiment 3, each “eventive” verb was tested once in the perfective aspect and once in the imperfective, with at least three other test items separating between the two test items for the verb. Sentences (15) and (16) illustrate these test items, where (17) is the question asked.

---

1Experiment 4 required a larger number of fillers than the other experiments, which made it necessary to have twice as many participants, and two different forms of the questionnaire.
“Last year, Omer, Boaz and Guy stabbed one another.”

“Rina entered the room and noticed Omer, Boaz and Guy stabbing one another.”

“Can you deduce from this that Guy stabbed Boaz?”

For each test item we collected the percentage of participants who answered negatively. A negative answer indicates that the reciprocal sentence can be interpreted as true in a situation where not all pairs between the three people appear in the relation denoted by the verb. We hence classify a negative answer as preference for a weaker reciprocal interpretation. A positive response to the question indicates a strong reciprocity interpretation, where the denoted relation includes all pairs between the different elements of the subject. The fillers contained sentences involving three people in various configurations and a different question about the situation than the question of the test items.

**Results**  Table 4.4 shows the verbs tested and for each verb, the percentage of participants who preferred the weaker reciprocal interpretation over the strong one. Due to a typo that was discovered in the questionnaire with the verb *no’em* (‘give a speech’), this item was excluded from the analysis.

<table>
<thead>
<tr>
<th>Verb</th>
<th>Translation</th>
<th>Perfective</th>
<th>Imperfective</th>
</tr>
</thead>
<tbody>
<tr>
<td>ro’e</td>
<td>‘see’</td>
<td>0</td>
<td>3.9</td>
</tr>
<tr>
<td>makSiv</td>
<td>‘listen to’</td>
<td>6.3</td>
<td>8.2</td>
</tr>
<tr>
<td>maxmi</td>
<td>‘compliment’</td>
<td>12.0</td>
<td>14.3</td>
</tr>
<tr>
<td>doker</td>
<td>‘stab’</td>
<td>16.0</td>
<td>31.3</td>
</tr>
<tr>
<td>Language</td>
<td>Label</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>somex al</td>
<td>trust</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Soxe`ax</td>
<td>forget</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>mefake`ax</td>
<td>supervise</td>
<td>13.7</td>
<td></td>
</tr>
<tr>
<td>sone</td>
<td>hate</td>
<td>19.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4: Preference for weaker reciprocal interpretations in Experiment 4
Chapter 5

Discussion

Experiments 1 and 3 both test preference of different verbs for different patient cardinalities. Experiment 1 uses forced choice between pictures illustrating a predicate concept with one or two patients. Such forced choice experiments are standard when testing other typicality preferences [e.g. 17]. Experiment 3 used sentence completion in a task of forced choice between a single patient and multiple patients. Both experiments show that there is a significant variability among transitive verbs with respect to patient cardinality. With a $p$-value of 0.05 and 53 subjects, 20 of the 32 verbs tested in Experiment 1 showed a preference for patient cardinality that is significantly different than chance: 4 verbs towards multiple patients and 16 towards a single patient. The other 12 verbs did not show any significant preference for patient cardinality. This experiment shows clearly that some verbs like ‘point at’, ‘shake’, ‘hit’ and ‘stab’, have a clear preference for one patient per agent. By contrast, other verbs – ‘give a speech’, and to a lesser extent ‘photograph’, ‘draw’ and ‘hug’ – have a preference for situations with two patients per agent. This is in agreement with common experience, where the former predicate concepts normally require a physical act directed to one location in space. By contrast, the latter concepts reasonably do not invoke this requirement. In the case of the predicate ‘give a speech’, a speech directed to one person is furthermore quite unlikely. Considerable consistency in patient cardinality judgements was found with the four predicates that were included in both Experiment 1 and Experiment 3: ‘point at’, ‘stab’, ‘scrape’ and ‘give a speech’.\footnote{Striving to test as many different predicates as possible, we only chose four predicates to be included in both experiments.} In both experiments, the verbs...
‘point at’, ‘stab’ and ‘scrape’ all displayed significant preference for a single patient, whereas ‘give a speech’ displayed a strong preference for two patients.

As said above, the MTH expects correlations between preferences of one patient per agent in instances of binary predicate concepts, and acceptances of “weaker” reciprocal interpretations with those concepts. Experiments 2 and 4 test for acceptability of strong reciprocal interpretations (full graphs) vis à vis weaker interpretations. Due to the similar experimental settings of Experiments 1 and 2 (picture-based settings) and Experiments 3 and 4 (text-based settings), we expect the stronger typicality-reciprocity correlations to hold of those pairs of experiments.

Experiment 2 tested preferences for reciprocal interpretations, in pairs of situations contrasting two kinds of configurations:

(a) Circular configurations (three pairs in the relation) vs. linear path configurations (two pairs in the relation).

(b) Complete configurations (six pairs in the relation) vs. circular configurations.

The results of the (a) test items show for all verbs a clear preference (94-100%) of reciprocal interpretations for the circular configuration over the path configuration. On their own, these results may be expected by the SMH: although both the path configurations and the circular configurations are not the maximal situations possible for the predicates tested, it may be supposed that participants, upon being forced to choose between them, choose the circular configuration, which is closer to the maximal configuration. The MTH also expects the preference of the circular configuration, since there is no reason we know to consider the path configurations as more typical for these predicate concepts than the circular configurations. Thus, the circular configurations exhibit reciprocity according to the MTH, or at least: they are closer than the path configurations to a situation that exhibits reciprocity.

In the (b) tests the results are quite different. All the (b) tests showed much lower preferences (34-76%) for the situation containing more pairs, compared to the (a) tests. This fact is not expected by the SMH: here, unlike the (a) tests, the circular configurations are visibly not the maximal configurations possible. Hence, the significant appearance of preferences for such situations as exhibiting reciprocity cannot be explained by the SMH alone. This leads to one of our main empirical conclusions:

**No Maximality:** Situations supporting reciprocal sentences do not necessarily in-
volve the maximal number of pairs possible in the relation denoted by the predicate antecedent of the reciprocal.

As discussed in Section 3, the MTH, unlike the SMH, expects reciprocity to be possible with non-maximal relations, provided that these relations are maximally typical of the predicate concept. Thus, the MTH expects a correlation between preferring circular configurations to complete ones in Experiment 2, and typicality of a single patient with the relative concepts in Experiment 1. Figure 5.1 shows the correlation calculated for all verbs in Experiments 1 and 2 except the verb no’em (‘give a speech’ see discussion below). The analysis (cf. Figure 5.1) shows a strong positive correlation (at +0.37), which is however statistically insignificant (Pearson correlation coefficient of 0.4). We attribute this to the poor distribution of values for patient cardinality typicality with the predicates we selected: all the predicates except ‘give a speech’ and ‘hug’ showed relatively strong preference for single patient interpretation. Although not statistically significant, the strong positive correlation leads us to expect that with a better distribution of the verbs across preferences for patient typicality, a more significant correlation may appear.

Moving on to Experiments 3 and 4, the MTH again expects a correlation between preference of a singular object in Experiment 3 and acceptance of the weaker interpretation of the reciprocal as tested in Experiment 4. We analyzed the correlation between the six eventive predicates that were tested in these experiments separately from the stative predicates. With the two aspects of each eventive predicate, the calculated correlation is given in Figure 5.2. In this case there is again a strong positive correlation, similar (at +0.36) to the correlation found with Experiments 1 and 2. Furthermore, in this case the correlation is statistically significant, with a Pearson correlation coefficient of 0.8. Thus, among eventive predicates a large portion of the variance in the acceptance of weaker reciprocal interpretations may be attributed to patient cardinality preferences, as expected by the MTH.

On top of this quantitative correlation between Experiments 3 and 4, they also show a qualitative correlation between changes in typicality/reciprocity preferences when comparing the perfective and the imperfective aspects of the same eventive verb. Regarding the eventive verbs in Table 4.3, the imperfective aspect shows an average increase of 0.9 (15%) in the preference of a single patient over the preferences observed in the perfective aspect. In correlation to that increase, the imperfective aspects shows an average increase of 0.03 (25%) in the acceptance of weaker reciprocal interpretations, compared to the perfective aspects. All individual eventive predicates except the verb doker (‘stab’) also show a qualitative
Figure 5.1: Experiments 1 and 2 – correlation between preference of circular configuration over complete configuration (weaker reciprocal interpretation) in Experiment 2, and preference of single patient in Experiment 1.
Figure 5.2: Experiments 3 and 4, six eventive predicates in the perfective and imperfective – correlation between acceptance of weaker reciprocity in Experiment 4, and preference of a singular object in Experiment 3

\[ y = 0.36x - 11 \]

\[ R^2 = 0.64 \]
correlation in the direction of the change of preferences between imperfective and perfective aspects. We consider these correlations as further support for the MTH:

**Typicality affects non-maximality:** One of the factors affecting non-maximality of the relation denoted by a predicate antecedent in a reciprocal sentence is this predicate’s typicality preference for single patients.

Apart from this evidence, which we consider to be supporting the MTH, the stative predicates tested in Experiments 3 and 4 did not show any support for our hypotheses. No correlation was observed between typicality preferences and reciprocal interpretations with the four stative verbs in these experiments. We believe that more research is needed about the factors that determine weaker interpretations of reciprocity with such verbs.

The behavior of another verb, no’em (‘give a speech’), challenges our hypotheses most dramatically. While in Experiment 1, this verb showed the strongest preference for two patients (92.5%), in Experiment 2 this verb did not show significant reciprocity preference for either of the circular/complete configurations. We speculate, however, that this should not be construed as counter evidence to the MTH. In fact, it is quite possible that ‘give a speech’ also shows a preference for agent cardinality and not only patient cardinality. Just like it is atypical to give a speech to one person, it is also quite atypical to be given two speeches simultaneously. As a result, the typicality of complete configurations (cf. Figure 5.3(a)) may in fact be lower than the typicality of circular configurations (cf. Figure 5.3(b)).

If this is the case, preferences for patient cardinality in situations with one agent, in opposition to our tentative experimental assumption, is not indicative of the typicality of such situations where more agents and patients are involved. In such cases, agent cardinality may also affect the interpretation of the reciprocal according to the MTH. We leave it for further research to study the effects on reciprocal interpretation in such cases.
(a) Each man is giving a speech to every other man
(b) Each man is only giving a speech to one man

Figure 5.3: Two situations for the expression *giving a speech to each other*
Chapter 6

Conclusions and Further Research

We proposed the Maximal Typicality Hypothesis, a modification of the Strongest Meaning Hypothesis, as a new principle for analyzing the interpretation of reciprocal sentences. Following Sabato and Winter [15], we proposed that the interpretation of reciprocals is directly derived by properties of the concept denoted by the binary predicate to which the reciprocal attaches. Thus, we implemented the MTH as formally generalizing the SMH, but employed a richer theory of predicate concepts than the “classical” theory of concepts presupposed by the SMH. Specifically, the typicality preferences of binary predicate concepts are hypothesized to play a major role in the logical interpretation of reciprocals. In order to check this hypothesis, we conducted a set of experiments involving reciprocal interpretations and typicality preferences with binary predicates. The correlations found between these different phenomena are claimed to support the MTH. Almost inevitably, the complexities of semantic judgements about reciprocals require further theoretical and experimental work.

In this work we addressed only typicality judgements about patient cardinality of a small set of relational concepts. Already in this work we show how patient cardinality typicality is not enough to account for reciprocal interpretation and how other kinds of typicality may also play an important role, such as in agent typicality in the relational concept underlying the verb ‘give a speech’. For relational concepts such as FOLLOW there may very well be even more complex typicality preferences at play. Obviously, a comprehensive study on the typicality preferences
of relational concepts, and their correlation to reciprocal interpretation is required.

In a different direction, [18] has shown that the SMH may in generalized into
a mechanism for plural prediction Consider the following sentences:

(18) The boys are sitting and eating.

(19) The boys are sitting and standing.

In sentence (18) all the boys are understood to be both sitting and eating. In
contrast, in (19) some of the boys are understood to be sitting while others are
standing (a ‘weaker’ interpretation than that of the previous sentence), being as
it is impossible for some boy to be both standing and sitting. Winter argues that
like for reciprocal expressions, the SMH may be generalized to explain variation
in such ‘stronger’ and ‘weaker’ interpretations of, e.g predicate conjunction. But
now let us consider also:

(20) The boys are playing and eating.

Employing Winter’s generalization alone, we would require a ‘strong’ inter-
pretation for sentence (20), one in which all the boys are both playing and
eating. Employing a generalization of the MTH upon Winter’s system, we might accept
a ‘weaker’ interpretation, one in which some boys are playing while others are
eating, justified by the assumption that it is not typical for someone to be simulta-
neously playing and eating. This research did not address Winter’s generalization
of the SMH and further work in this direction is certainly required.

The most important implication of our main proposals and findings though, is
that they point to some general connections between conceptual structure and the
logical behavior of natural language expressions.
Bibliography


השנעת הפרוש [&כפים] על הנ itch על ביטויים דדיים

 Nir Carm
השפעות הפירוט השיוופתי על הנינוחות של בניוימ הדרידים

חיבור על מחקר

לשם מחמי חלכן של הדרימאות לכסות החלך
ממעמי לממירים במידע המתחבש

גיר בר

חוני סטנגי והכימי - ממן טכנולוגיה לציונא
ארד הורשעל - חיתת
פברואר 2010
המשיכו הנושא בהנחיית פורפ', אליהם אדני בפﺥלתה להניעו המשך.

אצט רצה לנויעת התחד השתק בל ליתך על התרמית. העורר הילמיד והסבלות נא
חיל שחריפת פלן תמלץ הומדק ההבדלה בין לשנייה Ли על ספור נקודות ימי כסם
בסטטיווקוא, לעפיה סבעה וארבע תשובות השמתה המשך.

אצט מודע ל海淀ית הלקר שלاحتمה להجة על התמכי הנסף והנידך בהשכלה.
מודה

Technion - Computer Science Department - M.Sc. Thesis  MSC-2010-19 - 2010
תקציר

אחת הבילות היסודות במדינת המשמעויות של כתביים דידתיים כנ”ז היא זו.
ואז את העניין היא המשמעויות כוללה להשותל ביצ מפעלי למסגרות. בתוכי דלדנה
את משמעויות של הביתיו היסודי ‘ז אתה זה ‘בaffles במשמעויות הבאות:

(1) מקדה, ערבון יריב שמוסיפה את זה.
(2) מקדה, ר٭ ובשל שמוסיפה את זה.
(3) מקדה, ר٭ ובשל שמוסיפה את זה.

אז ניתן משפטים מעין על משפטים דידדיים. משפטים (1) נמער כעל˜ד
משלשאת האוניטים:’Bכילי, ר٭ ובשל שמוסיפה את שני האוניטים. כלמר, משפטים
וזה משמשו קירוב של ששו העיתים. ואת על כל זה סדר ברشعוש העיתים.aroo
אותו. לברות משפטים (2) שלונה משפטים (1) רכ בפעלי מבול הלוח, מער סימן
של ששו העיתים ארצי משמשו משפטים (2), במקוה, משמשו משפטים (2) פוך
 dbs.
 środowisk משפטים הלוח, פלק ששלשת האוניטים יצרו חד משלי אנשי בר
ar באוניטים להיתן בלארשรม נמר. משמשו משלי קירוב
רכ על העיתים ארצי וארש בלארשรม. ארצי שצומצם
ארח עד אמר על האוניס מבול. בסתור נמיאה עכ משמשו משפטים ארחי
מלתח לחשום משפטים דידדיים בנסף על השמיעה ארחי הזרמה שלה.

משרה על עבידה זו היא ל_condיו משעה במיסיפה ינabyrinth את משמשות
של כתביים דידדיים לועבי מתכון קירוב של המשמשות הפרטיים. הסופר
מצומצם את העיתים, הכללה התווית לש עית הערarseille היו משהות בוצות של
ipples המטרו’.’משמשו משפע תקיפות ההוקה בוזתיו (כלומר הכללה את
משמר המר בוזתיו לש עיתים בממשועות). היא מחיישוב על המשועהרoldt.

א
בקשה למקדחה בהמה והנני של תגובת המחשהණויה האפסי, אשר היא מקדחה
בومة תמרונים הפוליאומיל גלילו שמק申购 תגובת המרחק של דקמפר הוליצ'ן. יד ממקדים
מקדחה ומקדייםфункциית של מחשהченן של נוספים שמק申购 תגובת המרחק. דקמפר
שעונים בmaktורייה של הקונפטס של ליפidée שמק申购 תגובת סיבו של פלטפורמי. עם
יצמים של תהליך המר=-=-מקסימום והאת מקסימום יחסית. יד ממקדים
ذلك הליפidea של תגובת חפה איטר, ספתמקוח מקסימוס צירפ. מעסרו במקודח
בכת defamation.

בעברית וחצי וה擴ח על התמהحدود האפשרימי את תדונה והיצוג
של הקונפטס בנח LIMITED להנות תשביס הממשימים של זוכריembali של
המחלקה. המרת החדרה שאוה inputStream המנטיבת לוחיה usando מגנ småפ
מקסיים. לוחקת בחוסר מידע מחסיפה איצף. ספתמקוח מעדית וה淡水
לטפסותות של הפרידקט מקודח בלתי הדמי.

או ממסיכים את "השרשרת הממשויות הטריסטס הממסורות" (הלוך מ"ס). בטור
החלמה והחזרה חומר,CBS,הותרו" מנגנת יכול تخדרי אגדת הממשויות
המקודח בהוטıl על הטיפוסים המובילים בהח איפיציקט ישיחו.

הפות" ממקי שלמקפסות החוסי (relational concept) הביביס וימינו של הפרידקט.
כמי לקונפסות אחרון, יש העברות תסיפוסות לולד זימינים של זכרי
הפרידקט. בתאת ויסות אפרימונים בצעים יאסטרים תדה, והורג人們 נכלל
שופטיל ובו איים הגיא מסאם זאסה אתך איים תיימים ויתב חוסיפ
לטרק' מסאר מדול זאחה מח כאס הממסור נראו מסקר ציוע אוניא.

בעברית וחצי ומצעי מפרטיות פסיל והתשואות את תפרידקט
מקסימלי הביביס. אשר אליהם פסילשל הצעים של הפרידקט, לוחקת על יוזמה
לסק騎יתורפרידקטטיון.לסירה את הפרידקט על בבסי הזרדתי שירדינא
המת" ממקייפמטסמקומית של המעיטים ליכות למקסימוס לוחית פליקר.
לפי המפת המשוער ניתן את אמותביבס בת יז חיסון על התומח חיים
הabort condom ליתנייה של הפרידקט מקודח לוחית אגדה מקסימוס השל.

כדי להתחשב בצין פעלת המלת'ג הקב מתפישים את מיסיפא
ולא עור.ถนפט (3). (1) גות פתקים צביר לצור שהעמדת הרเนื่องจากסיטות של הפרידקט שמעון-
העונת ההפתע
מדינתית או פשואות קביעה זו הסיפת أجוז לייץ. למקפ, הקב' ממענה כי
המדל המקסימלי, אשר בגלי שמנים את גלא. מוע_vaבשת ממקאי
במסיפא (2). או בחר שמדליות באחרים כרור הפרידקט尽头 לאל חור
טריםיסיס כל. כו: על הפמיד', המקור של מודבט באת סיסטרמקסימוללק. יס

Technion - Computer Science Department - M.Sc. Thesis  MSC-2010-19 - 2010
ה adapté לוגו של חסמים. קלואר ממדים בו משעון האוניברס עמידים במגלה.

מתאימות למשטח (2) הגוים של המ💗 מנדלבך על אפל של המזרב. הר
שעון עם (3) הק שוגים. כשעריאנו לצליל, עז בר הפרדיקט 'לסרק' זגר טופוסי
עם אנטי נוומ לסרק פיזית בוד מארש לסרק עם פיזית. כל במשטף (3)
שלא כמי בשני המשטפים שקדעים של המנדלב המקריסים냅. האופטיר עזר הפרדיקט
לסרק עזר שלשה מיזחהוים והז מודל תופס פוחט ממודלים בוצל פוחט
החסיאה. זאא מיכר חמוד ולה.ForeColorי המקריסיםゴール למסגרות לטסק שיג אופטס
כז אוחו. עלות מודלים חולשת זאא במד המימדוסים מסקרוקו זאא לחז
כז אוחו. זאא תופס וחזר לפרדיקט למסקרוקו. עזר מפשט (3) הממגר ממנא מ
כז ממסירים בזאא כז אוחו משלשה המימדוסים מסקרוקו זאא לחז אוח
เมตรושאים על משטף (3) שגא לא נמי ליחס למסדרים אוטו אחד וחוזי היחסים
בהם במדים עבודת מיפסט או.