Event representations in collective and distributive readings: an on-line study

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Eingereicht von Garrett Smith
geboren am 3. November 1988
in Castalia, Ohio, Vereinigten Staaten von Amerika
Matrikelnummer: 526025

Erstgutachterin: Prof. Dr. Berry Claus
Zweitgutachter: Prof. Dr. Manfred Krifka

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Abstract

The structure of events described in collective and distributive sentences has been a much-discussed topic in the formal semantics literature on events. Here, the standard analysis of collective sentences involves a single event in which the plural subject takes part in as a whole. For distributive sentences, though, there is one sub-event for each atomic individual in the plural subject. How these analyses fit with the mental representations of events created on-line for these types of sentences has not been much studied, though. The experiment reported here employs a method for finding an interference between the mental representation of plurals and the task of indicating as quickly as possible that a single word was presented on a computer screen. Using this task on the verb of sentences in German, a mixed-effects model with crossed random effects for participants and items found the expected interference effect, which is taken to be the result of representing multiple sub-events in the distributive condition and only a single event representation in the collective condition. These results suggest that the event representations that we construct on-line have a complex structure, reflecting the structure proposed by the formal semantic analyses.
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Chapter 1

Introduction

1.1 Collective and distributive readings

Sentences with plural subjects can often have more than one reading. On the collective reading, all of the individual entities that make up the plural subject jointly carry out some action in a single event, such that that event could not have been successful without the participation of all of the individual entities working as a whole. For example, the sentence

(1) Mary and John carried a box together.

has a collective reading. (1) cannot be true unless there was an event of Mary and John as a group carrying a box. Distributive readings, on the other hand, involve each individual that is a part of the plural subject carrying out its own action in its own separate event. So, the sentence

(2) Mary and John each carried a box.

can only be true in the case that there were separate occurrences of box carrying by each of Mary and John. In formal semantics, these two readings have been the subject of numerous analyses with the goal of specifying how each of these sentences can have the meaning it has. There have only been a handful of experimental studies done on this topic, though, that investigate how people process sentences with these readings. This thesis is meant to contribute to the experimental study of collective and distributive readings while keeping an eye on the analyses and predictions from formal semantics.
The experiment presented in Chapter 2 closely follows the studies by Patson and Warren (2010, 2011). In these studies, the authors used an experimental paradigm which uses interference between visual stimuli and semantic plurality to probe the mental representations of sentences involving plurals. The sentences were presented in word groups of one to two words each on a computer screen. The participants’ task was to read the sentences word group by word group and to enter how many words appeared on screen in the word groups displayed in a different color. Patson and Warren found that reaction times were slower in those trials where the critical word was presented by itself, but denoted a plural. In other words, there was a Stroop-like interference effect between the semantic plurality of the words on screen and the need to carry out a task in response to a single word being presented. Whereas Patson and Warren used this task (hereafter “1/2 judgment task”) to investigate the representation of plural nouns, the experiment described in Chapter 2 uses this paradigm on event representations, comparing the on-line representations of distributive and collective sentences. The goal is to investigate whether multiple events are actually present in the on-line mental representation of distributive sentences.

Before I present this experiment, I first discuss previous research on events in collective and distributive readings, as well as experimental work related to the processing of collective and distributive sentences. In the second chapter, I report on the experiment proposed above. Finally, the last chapter discusses the results of the experiment in the context of the formal semantic and psycholinguistic literature on collectivity and distributivity.

### 1.2 Collectivity, distributivity, and events

At least since Davidson (1967), it has proven useful to include events in the semantic analysis of many types of sentences. Davidson originally argued for events in discussing adverbial modifiers such as “in the bathroom” or “with a knife” in action sentences like

\[(3) \quad \text{Jones buttered the toast in the bathroom with a knife.}\]

Such adverbial PPs pose a problem for traditional analyses of action sentences, as verbs can potentially take any number of adverbial modifiers. Assuming for now that action verbs denote n-place predicates, such tradi-
tional analyses simply insert a new argument for each new adverbial PP. So the sentence, “Jones buttered the toast,” would have the logical form \( buttered(j, t) \). Adding the modifier “in the bathroom” would then lead to the logical form \( buttered(j, t, b) \). This means, though, that the predicate \( buttered \) has a potentially infinite number of argument places, of which most are almost never used. Davidson suggests, therefore, that only one extra argument, an event argument, be added to the denotation of action verbs, and that the adverbial PPs be additional predicates modifying the event argument of the verb. So the denotation of \( buttered \) would now be \( buttered(agent, patient, event) \). Adding adverbial modifiers is then straightforward: simply add a new predicate of the event argument introduced by the verb as a conjunct to the logical form. The example from above now has the logical form

\[
(4) \begin{align*}
&\text{(a) Jones buttered the toast in the bathroom.} \\
&\text{(b) } \exists e[ buttered(e) \land \text{agent}(e, j) \land \text{patient}(e, t) \land \text{in}(e, b)]
\end{align*}
\]

This provided a solution to the problem Davidson initially set out to solve, that is, how to account for multiple adverbial PPs, but the idea of an event argument has proven useful in approaching many other issues in the semantics of natural language, among them differences in the event structures involved in collective and distributive readings. But first, I introduce some of the formal machinery assumed by much of the semantics literature on events.

In a number of more recent studies, the so-called neo-Davidsonian approach to event semantics is employed. In Davidson’s original analysis, verbs were predicates with slots for each of their usual arguments, plus one for the event argument. In the neo-Davidsonian approach, though, verbs are predicated of events alone, while their arguments are represented as separate thematic predicates (Maienborn, 2011). So, in a neo-Davidsonian analysis, (4-a) above will have the following logical form:

\[
(5) \exists e[ buttered(e) \land \text{agent}(e, j) \land \text{patient}(e, t) \land \text{in}(e, b)]
\]

This sentence is true just in case there exists an event such that the event was a buttering, the agent of the event was Jones, the patient of the event was the toast, and the event took place in the bathroom. Under this analysis, verbs denote sets of events of the type indicated by the verb (for example, \( walk \) denotes the set of all walking events), and these events are associated
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with their arguments by thematic roles.

A neo-Davidsonian analysis will be used in the event semantic analyses of collectivity and distributivity described below. But because much of that literature relies on theories of nominal plurality, I will first now discuss some of the work done on plurals in the nominal domain. It will first be necessary to discuss what is to be understood by the term “plural”. As discussed in Lasersohn (2011), a natural approach is that a plural noun holds true of only those groups\(^1\) of individuals whose members are all of the type denoted by the corresponding singular noun. So horses denotes a group of individuals who can all be described by the singular predicate horse. But, as Lasersohn (2011) shows, if groups only consist of more that one individual, then problems arise with sentences like

\[(6) \text{ No horses are in the corral.} \]

Sentences of this type (\textit{No A B}) are true iff there does not exist something of which both A and B are true. In a context in which there is only one horse, (6) is trivially true on the assumption that groups must contain more than one individual. In this context, horses does not hold of anything because there is only one horse, so there is nothing which is both horses and \textit{in the corral}, as is required by the truth conditions for sentences of this type. Even if the one horse were indeed in the corral, the (6) would still be true by the given denotation of horses. This problem can be solved if we allow plurals to contain not only groups, but also the individuals denoted by the corresponding singular. In that case, the truth of (6) is not trivial: if there is only one horse, the sentence can only be true iff that horse is not in the corral, because the single horse still falls under the denotation of horses.

One way to implement this formally is by the commonly used cumulative or pluralization operator *, as in Link (1983)’s influential analysis\(^2\).

The pluralization of a predicate \(P\), \(*P\), is the closure of \(P\) under the sum operation. In other words *\(P\) returns all the sums of individuals that are \(P\), as well as the individuals themselves, by the idempotent property of the sum operator \(+\) \((a + a = a)\). For example if \(\llbracket A \rrbracket = \{a, b, c\}\), then \(\llbracket *A \rrbracket = \{a, b, c, a + b, a + c, b + c, a + b + c\}\). This is a solution to the prob-

---

\(^1\)I follow Lasersohn in using the term “group” in a theory-neutral sense to mean simply a collection of entities denoted by a plural noun.

\(^2\)See also Bach (1986); Eckardt (2002); Kratzer (2008); Krifka (1989, 1990); Landman (1989); Link (1991); Maienborn (2011) for related analyses applied to event semantics.
lem discussed above in reference to (6). If there is only a single horse, the truth of (6) is not trivial, but depends on whether or not the single horse is in the corral or not, as one would expect. This is because there is an individual to which the predicate horses truthfully applies, namely the one horse, because the denotation of horses contains as a subset all individuals to which the predicate horse applies. It is important to note that, under Link’s analysis, there is no type distinction between plurals and singulars. The only difference is that plural individuals have other individuals as parts. Plurals are analyzed as aggregating the individuals denoted by a predicate into a single object, a sum or plural individual, to which some other predicate can apply.

In this connection, one last feature of the formalism is important, namely, the idea of an atomic individual. An atomic individual $x$ is an entity that only has itself as a part, that is, $x \leq x \land \neg \exists y [y \leq x \land y \neq x]$. This notion will be useful in the analysis of distributive sentences below. Note also that all of aspects of the formalism discussed so far (pluralization $\ast$, summation $\oplus$, part-of $\leq$, etc.) apply to the denotations of both nominals and events.

With this formalism, we can move on to an analysis of collectivity and distributivity in event semantics. Landman (1996)$^3$ presents a straightforward analysis of the collective/distributive distinction in terms of a neo-Davidsonian event semantics. In this analysis, verbs are functions from arguments into sets of events with the arguments filling thematic roles of the events. Since by definition of the $\ast$-operator, atomic events are also in the denotations of their pluralizations, Landman assumes that pluralization happens by default.

Collective predication is analyzed as a plural individual filling a single thematic role in a single (though by default pluralized) event, just the same as a singular individual. So, the sentence

\begin{equation}
(7) \quad \text{The boys gathered on the playground.}
\end{equation}

would be true just in case there exists some pluralized event – which also contains atomic events as well – that is a gathering, and the agent of that event is the boys as a group. Thus, Landman’s theory can account for the

$^3$Although there are numerous other analyses put forward in the formal semantics literature on the role of events in collective and distributive sentences (see footnote 2), I will adopt Landman’s for the fact that it neatly accounts for the types of sentences to be used in the experiment presented in the next chapter.
intuition that there is only one event involved in collective sentences.

Distributive readings, on the other hand, result from sums filling “plural roles” associated with plural events. Landman defines plural roles as follows. Let $R$ be a thematic role. A plural role $\star R$ for an event $e$ is the sum of all individuals filling $R$ in some $e'$ such that $e'$ is an atomic part of $e$. This ensures that each atomic individual in the plural subject fills a thematic role in its own atomic sub-event of the plural event denoted by the verb. For example, the sentence

\begin{equation}
(8) \quad \text{The boys slept.}
\end{equation}

is true if there exists some pluralized event of sleeping in which the boys fills the plural role of agent. This plural role is then split up into the individual agent roles of the atomic sub-events making up the pluralized event whose existence is asserted by the sentence as a whole. Notice that there are in effect two levels of events in distributive sentences. The sentence as a whole asserts the existence of a pluralized event, but this pluralized event is subsequently split up into sub-events associated with each atomic individual in the subject.

A major question in this thesis is at what level the events in distributive sentences are represented when people understand these sentences: at the level of the pluralized events or at the level of the atomic sub-events\(^4\).

### 1.3 Processing collectivity and distributivity

In Landman’s account, we saw a formal description of the way in which the events associated with collective and distributive sentences differ. This line of research has been studied very thoroughly by Landman and many others (see footnote 2 above). Compared with the formal semantic side, though, there have been relatively few processing studies of collective and distributive readings, and even fewer on event representations in these types of sentences.

One study related to event representations in processing is Gennari and Poeppel (2003). In two experiments, the authors compared eventive verbs (such as \textit{break}, \textit{discover}, or \textit{carry}) and stative verbs (like \textit{deserve} or \textit{possess}). Gennari and Poeppel take the most relevant difference between eventive

\[^4\text{In what follows, I will use the terms “plural event” and “sum event” to mean an event consisting of more than one atomic event. “Sub-event” will refer to an atomic event that is part of a plural event.}\]
and stative verbs to be implicit causality. The lexical meanings of eventive verbs are taken to be more complex than the meanings of stative verbs because they involve structured events with causal relationships between the participants in the events, whereas statives simply describe a relation with no causal implications. For example, the sentence

(9) John broke the glass.

implies that John caused the glass to become broken. This event structure is more complex than the simple relationship described by the sentence

(10) John deserves a raise.

which simply describes a static relation between John and a pay increase. Gennari and Poeppel tested to see if these differences in complexity in the described states of affairs between stative and eventive verbs could be measured behaviourally. Their first experiment used self-paced reading to compare reading times of eventive and stative verbs when used in complete sentences. They found that the reading times for eventive verbs were significantly longer than for statives. Their second experiment, using a lexical decision task, had a similar result. Stative verbs were recognized significantly faster than eventive verbs. The authors argue based on these results that this effect was caused by the differences in the complexity of the states of affairs described by the two types of verbs.

This study bears on the experiment presented in Chapter 2 in two ways. First, because the effect of semantic complexity was found at the verb in the self-paced reading experiment, the authors argue that event representations are built when the verb is processed. If this is indeed the case, it makes sense to look for possible effects of other types of event complexity at the verb, as well. Therefore, in the experiment described in the next chapter, the 1/2 judgment task was carried out on the word group containing the verb. Second, although Gennari and Poeppel’s experiment tested only the effect of lexical event complexity, it is possible that a similar effect might arise due to other types of event complexity. The difference in complexity between these types of verbs used by Gennari and Poeppel is a property of the lexical meanings of the verbs, not of higher-level semantic operations such as those used in Landman (1996) to explain differences between the event structures for collective and distributive sentences. But Gennari and Poeppel’s results
suggest that differences in the complexity of event representations can be detected by a behavioral measure like reaction time. If representing more than one atomic event causes a similar increase in complexity as does causal structure in lexically eventive verbs, then we should expect longer processing times for the more complex event representations of distributive sentences as compared to collective sentences, which only involve a single event. All in all, Gennari and Poeppel (2003)’s results lend support to testing the 1/2 judgment task on the verb in the experiment in Chapter 2, as well as to the general approach of looking for signs of more difficult processing where there are more complex event representations.

In a 1999 study, Frazier, Pacht, and Rayner looked at the on-line comprehension of collective and distributive sentences, though they did not explicitly investigate event representations. In an eye-tracking experiment, Frazier, Pacht, and Rayner (1999) found evidence for two principles regarding the processing of collective and distributive sentences. First, their study provides support for the theory that the distinction between collective and distributive readings is a matter of grammatical ambiguity and not vagueness or underspecification. Second, they found that sentences that are ambiguous with regard to the reading are initially assigned a collective reading. Their experimental sentences had either a collective or distributive reading which was made clear either before or after the predicate using “each” or “together”.

(11)  a. Sam and Maria carried one suitcase each at the airport.
    b. Sam and Maria carried one suitcase together at the airport.
    c. Sam and Maria each carried one suitcase at the airport.
    d. Sam and Maria together carried one suitcase at the airport.

There was a significant processing cost associated with the ambiguous distributive condition (11-a) in comparison to the other conditions, as indicated by longer first pass reading times, longer total reading times for the regions containing “each”, and higher percentage of regressions out of the region containing “each” and the region directly after that.

The two findings mentioned above follow from this data: If the collective/distributive distinction were simply a matter of vagueness or underspecification, there would have been no processing difficulty in the ambiguous distributive conditions. The intended reading would have simply been specified at “each” with no added processing cost. But the added processing
cost in the ambiguous distributive condition suggests that the participants had already defaulted to the collective reading and needed to revise their representation upon reading “each”.

The authors focus their argumentation on the finding that the difference between these types of sentences is due to grammatical ambiguity, not vagueness. This is important in that the language processor can be expected to consistently pick a parse if given an unambiguous sentence. Since in my experiment, I am interested in the differences in the representations of these types of sentences, the intended reading must therefore be clear in my critical items in order to avoid confounding disambiguation processes with differences in representation. How this was carried out in the present study is discussed in the materials section of Chapter 2.

In another study, Clifton and Frazier (2012) investigated factors affecting the collective or distributive reading of sentences containing conjoined NP subjects. Clifton and Frazier assume, based in part on Frazier et al. (1999), that conjoined NPs are summed by default to one entity, resulting in a collective reading. Their first experiment tested the reaction times for entering acceptibility judgments of sentences with conjoined NP subjects combined with predicates either biased toward a distributive reading (resign) or ambiguous as to reading (call). Sentences with an ambiguous predicate had the fastest reaction times on the acceptibility judgments. The authors interpret this result as reflecting the default summation of the conjoined NPs and the resulting collective interpretation of the predicate. The reaction times for the sentences with a distributive-bias predicate were slower, which the authors interpret as reflecting the participants’ having to split up the sum individual formed by the conjoined subject. Thus, these results suggest again, similar to Frazier et al. (1999), that the collective reading is the default reading. Also, this suggests that distributive readings might in some sense be “harder” to process because they involve splitting up a mental entity into its constituent parts. Note that this is compatible with the Landman’s formal analysis, in which collective sentences involve a single, plural individual filling a thematic role associated with the event denoted by the verb and distributive sentences involve splitting up the plural subject into atomic individuals which fill thematic roles in the atomic events making up the plural event denoted by the verb.

The second experiment in Clifton and Frazier (2012) used eye-tracking to
test how participants process anaphora referring to conjoined NPs introduced in a previous clause. Reading times were longer in the conditions in which a distributive anaphor referred to a conjoined NP than when it referred to individuals introduced separately, i.e., in separate clauses or sentences. These results suggest that conjoined NPs by default induce the summing of their conjuncts, which facilitates a collective reading, and that referents introduced in separate clauses tend to remain separate, facilitating a distributive reading. These two experiments suggest that we should expect differences in the processing of collective and distributive sentences, but they still leave open what role events play in on-line representations.

A study by Kaup, Kelter, and Habel (2002) focuses on the representations of plurals created in language processing and their effect on the reading of a sentence. First, the authors discuss two possible representations of plurals, “atomic-tokens” and “assemblage-tokens”. Under the atomic-tokens view, the referents of plural NPs are construed as groups of separate, atomic individuals to which predicates apply at the level of each individual. On the assemblage-tokens view, on the other hand, plurals are construed as undifferentiated groups which behave as wholes, and these wholes can be arguments of predicates. It is important to distinguish here between the representation of the objects denoted by linguistic expressions and the expressions themselves that can lead to these representations. Linguistic expressions can in principle trigger either representation, depending on a number of factors investigated in Kaup et al.’s experiments.

Intuitively, one might assume that the atomic-tokens representations are the default way of representing plurals. Kaup et al., though, argue against an atomic-tokens view of plurals and in favor of the assemblage-tokens view as the default representation of plurals, except in the case of partitive NPs, such as each of the orphans or most of the children. Such partitive phrases and quantifiers (“partitioning expressions”) pick out a subset of the individuals denoted by the nouns they precede. When used as the subject of a sentence, these partitioning expressions are associated with atomic tokens, where the predicate applies to each of the individuals in the NP.

In order to test how linguistic expressions and plural representations interact, Kaup et al. utilized the German anaphora sie (they) and beide (both), which exhibit properties of non-partitioning and partitioning constituents, respectively. To test the extent to which sie and beide differ in the type
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of tokens they require, Kaup et al. conducted two experiments. The first experiment used questionnaires to determine how people interpret these two anaphora. Participants filled out questionnaires, in the first part of which they were to indicate, for example, how many presents were brought in a variant of (12).

\[(12) \quad \text{a. } \text{Sie/beide brachten ein Geschenk mit.} \]
\[\text{b. They/both brought a gift.}\]

In the \textit{sie} condition, it is implied that there is only one gift involved, whereas in the \textit{beide} condition, there are two gifts. The authors found that \textit{sie} is interpreted as referring to an assemblage token by default, whereas \textit{beide} is interpreted as referring to atomic tokens by default.

In the second half of the questionnaire, participants rated the acceptability of sentences in which \textit{they} or \textit{both} was combined with an inherently collective predicate (e.g. \textit{meet at the movie theater}). Here, sentences with \textit{both} were rated less acceptable, since the collective predicate most easily applied to assemblages. So the takeaway from this questionnaire experiment is that \textit{sie} requires an assemblage token and is more compatible with collective readings, whereas \textit{beide} requires atomic tokens and is less compatible with collective readings. This finding is reinforced by their second experiment (measuring sentence reading time), in which they found that \textit{sie} could more easily be resolved to assemblage token representations previously constructed from the preceding text than to previously constructed atomic tokens.

In sum, these two experiments provide evidence that \textit{sie} is most easily associated with an assemblage token and is more compatible with collective sentences, and \textit{beide} is most easily associated with atomic tokens and is less compatible with collective sentences. I will take advantage of this finding in the materials used for the experiment reported in the second chapter by using \textit{sie} in the collective condition and \textit{beide} in the distributive condition. This should aid the participants in arriving at the intended reading in each condition. Since I am interested in how the event representations differ between the collective and distributive conditions, using these anaphora will help ensure that the readings the participants arrive at will be the ones I want to compare.

So far, we have seen that more complex (lexical) event representations lead to increased processing costs (Gennari & Poeppel, 2003), that collective
and distributive sentences are processed differently, with the collective being
the default reading (Clifton & Frazier, 2012; Frazier et al., 1999), and that
anaphora used in sentences create expectations about the types of mental
entities they refer to, which in turn influences what reading a sentence is
assigned (Kaup et al., 2002). I now turn to three studies that more directly
influence the experiment presented in the second chapter.

The experimental paradigm used in the present experiment, the Stroop-
like 1/2 judgment task introduced at the beginning of this chapter, was
first employed by Berent and colleagues (2005) to compare the mental
representations of singular and plural nouns. Participants were instructed to
indicate whether one or two words were presented on screen in a given trial.
The words could either be a singular or plural noun presented by itself (dog
or dogs), or two singular or two plural nouns presented together (dog dog
or dogs dogs). The authors found that reaction times were slower when a plural
noun was presented by itself than when a singular noun was presented by
itself. They argue that this interference was caused by the clash between
semantic plurality of the words and the task of indicating that only one word
was on screen.

The Berent et al. (2005) study established the 1/2 judgment task as an
index of when the mental representation created in response to a linguistic
stimulus (in this case, a noun) is plural. Patson and Warren (2010) extended
this methodology to complete sentences. In their first experiment, partici-
pants were instructed to read sentences presented centrally on a computer
screen in one- to two-word blocks. The last block in the critical sentences
was presented in blue, indicating to the participants that they should enter
whether that block contained one word or two words, just as in Berent et
al. (2005). The last word in the critical sentences was always a singular or
plural noun presented by itself, for example:

(13)  a. The hockey / player / knocked out / his front / tooth.
b. The hockey / player / knocked out / his front / teeth.

The slashes delineate the word groups. Similar to Berent and colleagues’
finding, reaction times were longer in those conditions where the last noun was
plural than when it was singular. Patson and Warren, therefore, replicated
Berent et al.’s interference effect between the semantic plurality of a noun
and the task of entering that that noun was presented by itself. Additionally,
they demonstrated that the 1/2 judgment task works on nouns embedded in complete sentences. In their second experiment, the authors manipulated both the plural marking on the last word and the reading. Using either a partitive subject (each of the ...) or the preposed adverb together, the test sentences had either a distributive or a collective reading, as in5 (14):

(14) a. Together the men carried a large box.
    b. Together the men carried some large boxes.
    c. Each of the men carried a large box.
    d. Each of the men carried some large boxes.

Once again, reaction times were significantly longer in the conditions in which a plural noun appeared by itself. But reaction times were also significantly longer for singular nouns when they were part of a distributive predicate than when they were part of a collective sentence. This suggests that the singular NPs in the distributive predicates were treated as if they were plural, i.e., more than one token was represented. These results show again that plurality – this time, plurality of mental representations of objects – can interfere with number judgements, and that the representations of distributive and collective readings do indeed differ, at least with regard to the number of object tokens represented.

In a similar study, Patson and Warren (2011) tested whether the 1/2 judgment task can be used to detect plural event representations. In the first experiment in the 2011 study, inherently distributive predicates (beep, yawn) were used to assess whether the 1/2 judgment task can index event plurality. The critical manipulation was the number of the subject NP.

(15) a. The machine in the lab quietly beeped at the technician.
    b. The machines in the lab quietly beeped at the technician.

With these inherently distributive verbs, there should be an event representation corresponding to each individual in the subject. So, in the singular condition, there should be one event representation, but in the plural condition, there should be multiple sub-event representations. Participants had to answer how many words were on the screen for the word group containing the...
verb, which in the test items always appeared by itself. In this experiment though, there was no difference in reaction time between singular and plural conditions. So, either this method does not index event plurality, or the inherent distributivity of a verb is not enough to force the representation of multiple sub-events in this task.

In a second experiment, the same method was used, but the material this time compared a plural definite description with conjoined singular NPs: the machines vs. the machine and the computer. In this experiment, reaction times were significantly slower in the conjoined condition as compared to the condition with plural definite descriptions. Patson and Warren argue then that the 1/2 judgment task is indeed sensitive to event plurality. There just has to be a strong enough cue to trigger a representation focussed at the level of the sub-event, such as separately introducing the referents taking part in the sub-events. A third experiment was carried out to ensure that the effect was not due to differences in the difficulty of building representations for the two conditions. There was no difference in reading times for the verb in either condition, so the authors argue that the effect in experiment two was indeed due to representing sub-events. The authors conclude that, in absence of explicit cues to force a distributive representation, these distributive conditions do not trigger a plural event representation as measured with this method, but given extra cues (in the form of a conjoined NP subject), a sub-event representation can result.

The findings of Patson and Warren (2011) beg the question of whether these results are indeed due to finer-grained event representations triggered by the manner of introducing referents or are simply due to the referents being introduced separately. It might have been the case that this result was actually due to the added complexity of processing a conjoined subject. So, we still do not have a definitive picture of whether distributive sentences really trigger multiple event representations. The experiment presented in Chapter 2 seeks to clarify the situation with the processing of these sentences by avoiding possible confounds such as conjoined NP subjects in the critical clauses.
1.4 Summary

In this section, we have seen that intuitions about collective and distributive can be given a formal characterization using the formalism developed in Landman (1996). Under this analysis, collective sentences involve a single event in which the plural subject as a sum takes part. Distributive sentences involve one event per atomic individual that is part of the plural subject. We have also surveyed the evidence for differences in the processing of collective and distributive sentences. Using the 1/2 judgment task, the experiment in the next Chapter should give us a clearer picture of how events are represented on-line when processing collective and distributive events.
Chapter 2

Experiment

The goal of the experiment presented in this chapter is to investigate the on-line representation of events in collective and distributive events. The results of Patson and Warren (2011) were suggestive, but the issue of how exactly events are represented on-line for distributive sentences and how these representations differ from the event representations of collective sentences was not resolved. The goal of the present experiment was not to investigate exactly what it is about sentences that determines the reading, but rather to make any difference in on-line event representation observable and thus to speak to the issue of whether the event representations of distributive sentences involve multiple sub-events.

If the hypothesized sub-events in the distributive condition are represented as multiple tokens, there should be an interference effect between this plurality of events and the task of entering how many words appear on the screen in the word group containing the verb, similar to Patson and Warren (2010, 2011) and Berent et al. (2005). This should be reflected in longer reaction times on the 1/2-judgment task in the distributive condition as compared to the collective condition, where, by hypothesis, there should only be a single event represented and thus no interference with the 1/2-judgment task.

2.1 Materials

All stimuli were in German and can be found in the Appendix. There were 48 sentences total, including 16 test items. All stimuli were divided into one- to two-word groups, with the last word group always marked as the one
CHAPTER 2. EXPERIMENT

for which the participants must decide whether one or two words were in that word group. The test items had the following form. A matrix clause introduced two referents who carry out some action on an object, which is modified in a relative clause containing either \textit{beide nacheinander} (both one after the other) (distributive condition) or \textit{sie zusammen} (they together) (collective condition), which refer to the individuals introduced in the matrix clause.

As discussed above, Patson and Warren (2010) found an interference effect when using the 1/2-judgment task on direct objects in distributive readings. In order to avoid a similar effect from possibly concealing plural event representations, the direct object in the critical clauses was referred to with a relative pronoun so that only one token for the direct object can be represented.

The adverbs \textit{nacheinander} and \textit{zusammen} serve to reinforce the distributive and collective readings, respectively, and should aid in making the intended event structure clear in each condition \textit{Nacheinander} emphasizes the fact that separate events took place, one after the other, which coincides with \textit{beide}’s preference for referring to atomic tokens, which can be more easily incorporated into a distributive predicate (Kaup et al., 2002). Additionally, Reis and Vater (1980) found that \textit{beide} is only acceptable when combined with distributive predicates, which should strongly encourage the distributive interpretation, especially when combined with \textit{nacheinander}. \textit{Zusammen}, though, rules out more than one event, reinforcing the default collective reading of \textit{sie} (Kaup et al. (2002), Clifton and Frazier (see also 2012); Frazier et al. (see also 1999)). Here is an example test item in both versions, collective and distributive; the rest of the items are listed in the Appendix.

(1) Collective:
\begin{quote}
\textit{Die Jungen Finn und Martin haben eine neue Holzeisenbahn bekommen, mit der sie zusammen vergnügt spielen.}
\end{quote}
The boys Finn and Martin received a new wooden train set, which they are happily playing with together.

(2) Distributive:
\begin{quote}
\textit{Die Jungen Finn und Martin haben eine neue Holzeisenbahn bekommen, mit der beide nacheinander vergnügt spielen.}
\end{quote}
The boys Finn and Martin received a new wooden train set, which they happily play with one after the other\(^1\).

In constructing the test items, verbs for the critical clauses were selected that were neither inherently collective (such as *gather*) nor inherently distributive (like *sleep*), but instead could have either reading depending on the context. This contrasts with Patson and Warren (2011)’s experiment, in which only inherently distributive verbs were used. The verbs in the present experiment were selected in order to allow direct comparison of the two readings. Using these verbs means that the only difference between conditions at the location of the 1/2-judgment is the reading, which is determined earlier in the sentence.

A total of 36 filler items were used, four of which served as the stimuli in the practice section of the experiment. The remaining 32 fillers were used in the experimental section. The fillers were superficially similar in form to the test items: each filler contained a matrix clause introducing two referents who carried out some action with regard to an object. The object, the referents, or the action described in the matrix clause was then modified in the relative clause. For half of the filler sentences (which is one third of the total sentences), there was a corresponding comprehension question\(^2\). An example of a filler item and its corresponding question are in (3) and (4). The rest of the filler items can be found in the Appendix.

(3) Filler sentence:
*Die Klavierspieler Alexander und Ulrike haben eine klassische Sonate eingeübt, die sehr schwierig ist.*

The pianists Alexander and Ulrike learned a classical sonata which is very difficult.

(4) Comprehension question:

---

\(^1\)Note that, in the English translation of the distributive condition in (2), there is a habitual or repetitive reading which is not as easily available in the German original. In the German version, the playing is understood to take place only once. The same is true of the collective condition.

\(^2\)Due to an error by the experimenter, the first nine participants used a version of the materials that contained errors in two of the comprehension questions. In these two cases, the names in the comprehension questions did not match the names in the respective filler sentences. See the Appendix for the questions with errors and the corrected versions. The corrected versions of the comprehension questions were used for all participants after the ninth.
Spielen Alexander und Ulrike Klavier?
Do Alexander and Ulrike play piano?

2.2 Method

2.2.1 Participants

30 participants took part in the experiment (9 male, 21 female). All were right-handed and native speakers of German. Their ages ranged from 20 to 34 years old. In a questionnaire after the experiment, none of the participants reported figuring out what was being tested in the experiment.

2.2.2 Design

The experiment had one factor (version) with two levels, collective and distributive.

The stimuli were divided into four participant lists, which differed in the order of items. The lists were paired such that within each pair, the test items were in identical conditions, differing only with regard to the ordering of the items. Thus in the analysis, the pairs were considered to be identical. The lists were matched for average length of the critical verb in characters and average number of syllables (see Table 2.1). The lists always began with three fillers and ended with a test item, with a pseudo-random distribution of test and filler items in between. Participants were randomly assigned to a list.

2.2.3 Apparatus and Experimental Conditions

The experiment was set up and run using Experiment Builder software version 1.10.165 from SR Research. Stimuli were presented on a 17-inch Belinea LCD monitor with a refresh rate of 60Hz at a resolution of 1024 by 768 pixels in 32-bit color controlled by an ATI Radeon 7000 AGP graphics card with 32MB of memory. The text was printed in 20-point Arial font in light grey against a black background. Critical word groups (containing the last word in the embedded clause in the test sentences) were presented in yellow. Two NESU Push-Button-Boxes, each with two buttons arranged horizontally, were used to control the experiment and measure response times. On the left button box, the right button was used for progressing to the next
2.2. METHOD

Table 2.1: Average number of syllables and average length in characters for the critical verbs in each item group.

<table>
<thead>
<tr>
<th>Item group</th>
<th>Avg. Syllables</th>
<th>Avg. Length in characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>8</td>
</tr>
</tbody>
</table>

word group and for answering “yes” on the comprehension questions. The left button on the left box was for answering “no” on the comprehension questions. The right button box was used exclusively for entering how many words were presented in the critical word groups, the right button for entering “1” and the left for “2”. Overhead lighting and natural light from windows illuminated the room. The experimenter was present in the room for the duration of the experiment.

2.2.4 Procedure

One participant was tested at a time. After giving their informed consent, participants read a print-out of the instructions for the experiment (see Appendix). An experimental trial ran as follows. A fixation cross was displayed centrally on the computer screen. When the participants were ready, they pressed the next/yes-button to see the first word group in a sentence. Sentences were displayed in small word groups of one or two words each. In the experiment as a whole, there was an equal number of one- and two-word groups. Each successive word group appeared on the screen with each press of the next/yes-button on the left button box, replacing the previous word group. Participants were instructed to read the sentences at their normal pace, but carefully so that they would understand them. The last word group in all sentences contained (at least) a verb and was displayed in yellow. All 16 of the test items and eight of the fillers ended in a one-word group, and the remaining 24 fillers ended in a two-word group, so that there was an equal number of one-word and two-word groups (24 each). The participants were instructed to enter how many words were displayed in the yellow word group as quickly and accurately as possible using the right button box, and their reaction times were measured in milliseconds. After half of the filler items, there was a yes or no comprehension question to be answered using the left button box. After a practice session consisting of four
filler items, two of which had comprehension questions, the experiment began. Participants were allowed to ask questions after reading the instructions and after the practice session, but not during the actual experiment. Finally, after the completing the experiment, participants filled out two questionnaires: one about the experiment itself and one about the participants’ demographic information and handedness.

2.3 Results

There were two participants who made four errors in answering the comprehension questions\(^3\). A binomial test showed that this error rate (four wrong answers out of sixteen questions) was not significantly different from chance \((p = 0.0768)\). Therefore, these two participants were removed from the rest of the analysis, leaving 28 participants. The mean error rate on the comprehension questions for these 28 participants was 1.21 wrong answers out of sixteen questions. No participant made more than one wrong response on the 1/2-judgment task, and none of the wrong responses were on critical items. Therefore, only correct responses were included in the further statistical analysis.

The data were analyzed using R (R Core Team, 2012) and the R package \textit{lme4} (Bates, Maechler, & Bolker, 2012) for mixed effects modeling. Outliers were identified via visual inspection of the scatter plot, which showed that 3000ms was a reasonable cut-off. Thus, reaction times longer than 3000ms were excluded from the data analysis \((N=2; 0.4\% \text{ of the total number of reaction times})\) The overall mean reaction time for the distributive condition \((M = 936.7483\text{ms}, SD = 224.8413)\) was longer than the mean reaction time for the collective conditions \((M = 918.6029\text{ms}, SD = 359.8027)\).

Mixed-effects modeling with crossed random effects for participants and items was used to model the data. A stepwise variable selection procedure was used to determine the fixed- and random-effects structures of the model, using likelihood ratio tests to select models that best describe the data. The initial model included \textit{Version} (collective vs. distributive), \textit{Participant Group} (I or II), \textit{Trial} (the ordinal position of the item in the test phase), \textit{Length} (the number of letters in the verb), and their two- and three-way interactions.

\(^{3}\)The participants who saw the comprehension questions in which the names did not match the corresponding filler sentences did not perform differently than the participants who saw the corrected materials.
2.3. RESULTS

Table 2.2: Likelihood ratio test comparing the model with the final fixed- and random-effects structure described in the text with an otherwise identical model without VERSION as a fixed effect.

<table>
<thead>
<tr>
<th>Df</th>
<th>AIC</th>
<th>$\chi^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model without VERSION</td>
<td>18</td>
<td>6133.9</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>19</td>
<td>6128.0</td>
<td>7.9391</td>
</tr>
</tbody>
</table>

as fixed effects. Starting with this fixed effects structure, the random effects structure of the model was set, with likelihood ratio tests resulting in random intercepts for participants and items and by-participants random slopes for the effect of LENGTH, TRIAL, and READING. The fixed-effects structure was then adjusted by progressively removing fixed effects, starting with the highest-level interactions with the lowest t-value. If a likelihood ratio test showed that the simpler model was a better fit for the data (as measured by AIC) than the more complex model, the simpler model was chosen, and the process repeated. If there was no significant difference between the models, the model using fewer fixed effects was selected. At the end of this process, the last model had fixed effects for VERSION, PARTICIPANT GROUP, TRIAL, and LENGTH, as well as the interactions between VERSION and TRIAL and between TRIAL and LENGTH. A likelihood ratio test comparing this model with one with VERSION removed, but otherwise identical, was significantly worse than the final model, as shown in Table 2.2.

This model was then subjected to model criticism as described in Baayen (2008) and Baayen and Milin (2010) in order to eliminate overly influential outliers. Reaction times with absolute scaled residuals greater than 2.5 standard deviations from the mean were removed (2.24% of the data), and a new model was fitted. Compared to the model before criticism, this final model (after model criticism) better accounts for the data, as indicated by a higher $R^2$ (0.7516) than the previous model’s the $R^2$ (0.6797). Note that these $R^2$ values describe the variance accounted for by each model as a whole, not variance accounted for by the fixed effects alone (Baayen, 2008). The final model after model criticism will be the one referred to for the rest of this thesis.

The standard deviations for the random-effects structure are listed in 2.3. The coefficients, standard error, and t-values of the fixed effects in the final
Table 2.3: Summary of the random-effects structure of the final model. Total number of observations: 436; groups: Participant, 28; item, 16

<table>
<thead>
<tr>
<th>Groups</th>
<th>Name</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant:</td>
<td>Intercept</td>
<td>324.1376</td>
</tr>
<tr>
<td></td>
<td>TRIAL</td>
<td>0.3770</td>
</tr>
<tr>
<td></td>
<td>LENGTH</td>
<td>37.3569</td>
</tr>
<tr>
<td></td>
<td>READING</td>
<td>60.6705</td>
</tr>
<tr>
<td>Item</td>
<td>Intercept</td>
<td>49.1656</td>
</tr>
<tr>
<td>Residual</td>
<td></td>
<td>158.3895</td>
</tr>
</tbody>
</table>

model are given in Table 2.4. Given that it is unclear how to best calculate degrees of freedom for mixed models, p-values are not given. Instead, t-values with an absolute value greater than 2 will be considered significant (Baayen, Davidson, & Bates, 2008). First, there was a significant effect for VERSION such that the difference between the distributive and collective conditions was about 140.39ms ($t=-4.047$), with the distributive condition taking longer than the collective. This is the result expected in light of Patson and Warren (2010, 2011)'s findings. Next, there were significant effects for PARTICIPANT GROUP and TRIAL. The participants in participant group I were on average faster than participant group II by about 184.83ms ($t=3.539$). The effect for TRIAL was such that for each successive item, the average reaction time dropped by about 1.37ms, a small, but significant difference ($t=-5.214$). LENGTH did not reach significance but was included as a fixed effect because it was involved in a significant interaction with TRIAL and also because it was included in the random-effects structure. Finally, there were two significant interactions: one between VERSION and TRIAL ($t=3.546$) and the one between TRIAL and LENGTH ($t=3.124$).

Thus, the expected effect was found, namely that the distributive condition had significantly longer reaction times than the collective condition, indicating interference between a mentally represented plurality of events and the task of entering that one word was presented on screen in the critical word group. In the final chapter, I discuss these findings in light of the theoretical and experimental literature discussed in the first chapter, as well as directions for future research.
2.3. RESULTS

Table 2.4: Fixed effects for the final model after model criticism and their associated intercept estimates, standard errors, and t-values.

<table>
<thead>
<tr>
<th>Fixed Effects</th>
<th>Estimate</th>
<th>St. Error</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1002.9078</td>
<td>112.7138</td>
<td>8.898</td>
</tr>
<tr>
<td>Reading = collective</td>
<td>-140.3891</td>
<td>34.6857</td>
<td>-4.047</td>
</tr>
<tr>
<td>Participant Group = II</td>
<td>184.8262</td>
<td>52.2207</td>
<td>3.539</td>
</tr>
<tr>
<td>Trial</td>
<td>-1.3747</td>
<td>0.2637</td>
<td>-5.214</td>
</tr>
<tr>
<td>Length</td>
<td>-2.8920</td>
<td>12.5561</td>
<td>-0.230</td>
</tr>
<tr>
<td>Reading:Trial</td>
<td>0.3588</td>
<td>0.1012</td>
<td>3.546</td>
</tr>
<tr>
<td>Trial:Length</td>
<td>0.0946</td>
<td>0.0303</td>
<td>3.124</td>
</tr>
</tbody>
</table>
Chapter 3

Discussion and Conclusion

The goal of the present study was to compare the mental representations of events created on-line when reading collective and distributive sentences. In the formal semantics literature, collective sentences involve a single event in which the plural subject takes part as a whole. Distributive sentences, on the other hand, are analyzed to have one event per atomic individual in the subject. The experiment reported in the last chapter was designed to test whether the event representations people actually create when reading these types of sentences have a similar structure to the event structures given in the formal semantics literature.

It was hypothesized that if the 1/2 judgment task can be used to detect plural event representations and the implicit sub-events in distributive readings are represented separately in on-line sentence processing, there should be interference between the representation of the plurality of the event representation and the task of indicating that only one word was presented on the screen, as reflected by longer reaction times in the distributive condition on the 1/2 judgment task. This was, in fact, the case in the results reported in the previous chapter. Reaction times on the 1/2 judgment task were significantly longer in the distributive condition than in the collective condition. Thus, the results of this study provide support for the hypothesis that distributive readings of sentences involve event representations of multiple sub-events. This contrasts with the event representations of collective readings, which are hypothesized to involve a single event associated with one plural individual that is the plural subject. The results of this experiment parallel the findings of Berent et al. (2005) and Patson and Warren (2010,
In the next section, I discuss how the results of the present study fit in with previous research on collective and distributive sentences. Then, I touch on the issue of what it is that allows us to determine the reading of a sentence, as the formal and experimental literatures seem to take different perspectives on this. Finally, the last section concludes, noting possibilities for future research.

3.1 Relation to previous findings

The results of the present experiment contribute to the existing literature in a number of ways. First, these results confirm that the method introduced in Berent et al. (2005) (the 1/2 judgment task) can be an effective method for investigating the representation of plurals by using a Stroop-like interference effect between plural mental representations and having to take action in response to the perception of a single object.

Using the 1/2 judgment task on direct object nouns in collective and distributive sentences, Patson and Warren found the interference effect for singular nouns in distributive sentences. They interpreted this as evidence for multiple object tokens being represented in the distributive condition compared to a single object token in the collective. Patson and Warren do mention in their discussion, though, that their results leave open whether the interference they found was due to separate object tokens or separate event tokens. In principle, the interference effect Patson and Warren found with the 1/2 judgment task on the object noun could have actually reflected a plural event representation instead of a plural object representation. I think this is likely not the case, though, since Berent et al. (2005) showed a strong interference effect when using nouns. Also, Patson and Warren (2010) tested on the word group containing the critical nouns in both experiments. By contrast, the results of the present experiment speak clearly in favor of plural event representations, especially because the number of the object token in the critical clauses was always singular, which makes a confound between the number of object tokens and the number of event tokens unlikely. In addition, the 1/2 judgment task was done at the word group containing the verb, which, given Gennari and Poeppel (2003) and Patson and Warren
(2011)’s results, should give access to the event representation instantiated by the verb.

Next, the present experiment follows Patson and Warren (2011) in utilizing the 1/2 judgment paradigm to study event representations instead of the representation of nouns, strengthening their finding that events can be mentally represented as plurals, at least under certain conditions. In their 2011 study, Patson and Warren investigated the representations of events in distributive sentences only. In the first experiment in that study, only inherently distributive predicates with either singular or plural subjects were used, the hypothesis being that if the event representations of distributive sentences involve one event token per atomic individual in the subject, there should be a significant interference effect in the 1/2 judgment task in the plural condition due to the multiple event representations interfering with the 1/2 judgment task. They found no significant difference between the singular and plural conditions, though. Unlike in the present study, the materials in Patson and Warren (2011)’s first experiment were not set up so as to emphasize the separateness of the sub-events in the plural condition. The materials relied instead on the inherent lexical distributivity of the verbs. It could be, then, that these sentences, lacking overt cues to the event structure of the whole sentence, triggered event representations that were underspecified with regard to the number of events. Alternatively, the sentences might have been represented at the level of a single sum event consisting of the sub-events in which each individual in the subject had the thematic role of agent, without actually splitting up this sum event. In other words, because the sentences did not overtly emphasize that there were separate sub-events, these sub-events were not represented, and a less detailed sum event representation was constructed.

The materials in the present experiment, on the other hand, were structured in such a way as to emphasize the sub-events in the distributive condition and the fact that there was only a single event in the collective condition. The results suggest that the mental representations of collective and distributive sentences indeed differ with respect to the number of events represented as a result of the overt cues (subject pronouns and adverbial phrases) intended to make the reading clear in each condition. It seems, then, that sentences that emphasize the sub-event structure are more likely to lead to event representations that reflect this level of detail. Conversely,
sentences that do not draw attention to the sub-event structure will be more likely to induce representations that are either underspecified represented at the coarser level of a sum event. The second option (sum event representation) is consistent with formal semantic theories, such as Landman (1996), according to which sentences assert the existence of an event, which can then be split into sub-events in distributive readings. In sentences such as those in Patson and Warren (2011)’s first experiment in the plural condition, the mental representation might involve only a single sum event because there are no overt cues that could lead to a representation at the sub-event level of granularity.

In the second experiment in that study, though, reading times for the conjoined-NP condition (“the machine and the computer beeped...”) were significantly longer than the simple-plural subject conditions (“the machines beeped...”), which the authors interpret as evidence for differing event structures resulting from the stronger cue of the individuated agents. This is again evidence that event representations reflect the level of granularity given in the sentences they result from. That is, if a sentence has strong cues for a finer-grained event structure at the level of sub-events, a finer-grained event representation will be constructed. But if the sentence lacks strong cues for a more detailed structure, a representation underspecified with regard to the sub-event structure will result. The present study provides evidence that event representations can be plural, but they will only be represented as plural when there are strong enough cues to warrant the more differentiated representation.

The data from Berent et al. (2005), Patson and Warren (2010, 2011), and the present experiment show that this experimental paradigm can be used to study the mental representation of plurality in a variety of contexts: single nouns, nouns part of complete sentences, and events denoted by sentences. This suggests that the plurality is a salient property for multiple types of mental representations, and that the 1/2 judgment task is flexible as to the type of plural objects that it is sensitive to. Because of that, this task has the potential for use in studying plurality in other linguistic contexts as well (see Future Research below).
3.2 The locus of distributivity

Though this experiment was not designed to explicitly test where and how people arrive at a particular reading for a sentence, I believe the results can speak to this issue, at least provisionally. Most theories of collectivity and distributivity, including Landman (1996), assume that the reading of a sentence is determined by the verb in combination with the pluralization operator. A clear case of this is inherent or lexical collectivity and distributivity. Certain verbs only allow one reading or the other such as gather (collective reading only) or sleep (distributive reading only):

(1) The children gathered at Mary’s house for a slumber party and fell asleep late.

Since a gathering is something that can only be carried out successfully by a group as a whole, the first conjunct in (1) receives a collective reading. The second conjunct, on the other hand is distributive, as falling asleep is not something a group can even do. Only the individuals making up the group can fall asleep. So, for sentences like this and many others it makes sense to assume that a collective or distributive reading results from the verb. In Landman (1996), we saw that this concept was implemented by pluralizing the denotations of verbs by default, since by the definition of the $*$ operator, singulars are a subset of plurals. In the case of inherently collective and distributive verbs, there seems to be an added constraint restricting each type of verb to the subset of events it can actually have as a denotation. So, even though the denotations are pluralized, inherently collective verbs cannot actually denote a plural event, and the reverse is true of inherently distributive verbs. They simply cannot denote atomic events, but rather must denote a sum event with an associated plural role.

But in sentences with verbs that can accommodate both readings, the story cannot be so simple. Consider the following example:

(2) The workers carried a box and pushed a cart.

In this case, collective and distributive readings are possible in both conjuncts. This means that not all verbs come with a built in restriction to either atomic or plural events, and simply having both denotations available is not enough to tell us in a given context what the reading should be. All this suggests
that the locus of the collective/distributive distinction is not solely at the verb, at least for verbs that can have both readings.

With these considerations in mind, I will now sketch an incremental processing model of how the language processor comes to settle on a reading for a sentence. Given the results in Frazier et al. (1999), Clifton and Frazier (2012), and Kaup et al. (2002), I will assume that the collective reading is the default reading, and if no other information in the sentence or context contradicts that, the language processor will settle on a collective reading. In addition to fitting well with the studies just mentioned, this part of the model is also compatible with Landman (1996)’s analysis in which collective sentences involve a single event associated with a single sum individual filling a thematic role. Intuitively, this seems like a simpler operation than splitting up a sum individual in order that it can fill thematic roles in atomic sub-events making up a plural event. Indeed, Kaup et al. (2002) found increased processing difficulty when participants had to split up an assemblage token.

If there is a cue in the linguistic input, the processor can switch from the default collective to the distributive reading. This can come in the form of in the form of partitive or quantificational subjects (Patson & Warren, 2010), adverbs such as each (Frazier et al., 1999) or nacheinander (the present study), or the anaphor beide (Kaup et al., 2002, and the present study), for example. Such elements can, especially in combination, force the language processor to revise its default collective interpretation, as Frazier et al. (1999) argued as well.

This process must begin before the verb is encountered, assuming the verb is not the first constituent in the sentence. In all of the studies cited as well as the present one, the verb was not the first word participants encountered. The most extreme case is the present study, in which the verb in the critical clauses was the very last word in the sentence. And because there was no overt difference between conditions at the verb, the event structures must have at least started to be formed before the participants encountered the verb. Patson and Warren (2010) and Frazier et al. (1999, in half of the conditions) also made the intended reading clear before the verb. Therefore, I propose that a single minimal event representation is instantiated whenever a new clause is encountered, which parallels the Landman (1996) and others’ analyses in which sentences are taken to assert the existence of an event. This event representation could in effect be what Radvansky and Zacks (2010)
calls an event model, which is a type of mental model. This minimal event representation created in language processing could, following Radvansky and Zacks (2010), incorporate information of spatiotemporal location, the entities involved, salient properties of the entities and the relations between them, as well as linking relations to place the event representation currently being constructed to other existing event representations from the discourse. These features can either be specified by the linguistic input, or remain underspecified if no relevant information is encountered.

So, when the language processor encounters new linguistic input, it initiates a minimal event representation. As more of the input is encountered, the processor fills in information in the minimal event representation, such as the entities involved. Upon encountering a cue for a distributive reading in the input, the processor splits the developing representation into sub-event representations and associates the atomic entities from the plural subject with a thematic role in a sub-event representation.

Recall that in Landman (1996), verbs denote sets of events of a certain type along with their associated thematic roles. For example, the verb walk denotes the set of all walkings and their associated agents. Similarly, in the proposed model, verbs play a similar part. They supply the type of event being represented. The event representation starts out minimal, but once the verb is encountered, the type of event becomes clear and the exact thematic roles the arguments of the verb take are made clear.

If not already specified by other constituents in the sentence, it is conceivable that inherent distributivity (as in Patson and Warren (2011)) might not be enough to trigger a change in the event representation from the default collective reading with a single event representation. In that case, the representation of collective and distributive sentences verbs would not differ as to the number of event representations. So, under this model, the null effect in Patson and Warren (2011)’s first experiment might have been caused by a lack of overt cues to distributivity and the fact that the inherent distributivity of the verbs was not enough to cause the sum event to be split into sub-events. But in the present experiment, there were multiple cues to distributivity, so the processor was able to overcome the default collective representation and split the event representation into sub-event representations.
This model is provisional. A full model of processing for collective and distributive sentences would require extensive empirical and theoretical testing. But I believe this model captures the basic facts of the studies discussed in this thesis, and to the extent that it makes testable hypotheses, it can certainly serve as a starting point for future studies.

3.3 Conclusion

In this thesis, I have discussed formal semantic analyses and experimental findings regarding the structure of event representations in collective and distributive sentences and presented an experiment investigating the mental representation of events as they are created on-line when reading these sentences. In formal analyses, collective readings involve a single event paired with a plural individual made up of the sum of the individuals in the plural subject. In distributive readings, on the other hand, there is a sum event denoted by the sentence as a whole, which is subsequently split into sub-events, one per atomic individual in the plural subject.

The experiment presented here makes use of the 1/2 judgment task, which can be used to detect interference between the semantic plurality of linguistically described objects or events and the task of entering the number of words appearing on a computer screen. It was found that the reaction times on this task were significantly longer in the distributive condition than in the collective condition, which is indicative of a plural event representation for distributive sentences. In this way, the experiment provides evidence for mental representations comparable to the formal analyses: one event representation for collective sentences, and one event representation for each atomic individual in the plural subject for distributive sentences. The results of this experiment suggest that plural events in distributive sentences are indeed represented at the level of sub-events split off from the sum event representation created for the sentence as a whole. Distributive event representations differ, therefore, from collective event representations, which involve a single event representation.

3.3.1 Future research

This study enhances our knowledge of event representations created on-line in the processing of collective and distributive sentences, but there is still more
to be explored in this area. One area for future research is the exact roles that zusammen (together) and nacheinander (one after the other) and beide (both) and sie (they) play in determining the structure of event representations. In this study, two combinations of these four elements (sie zusammen and beide nacheinander) were used to make the intended reading clear in the hopes of having the best chance at detecting a difference in event representations if there was one. Since evidence for different event representations for the two readings was indeed found with these materials, a next step would be to investigate each element’s contribution to the event representation separately. The experiment could be repeated without zusammen and nacheinander to test for possible differences resulting exclusively from the manipulation of the subject pronoun. I anticipate that there would still be a detectable difference in event structure between conditions, though the effect could very likely be smaller, since there would be one less overt cue as to the intended event structure.

Another way of examining these adverbs would be to hold the subject pronoun constant – using only sie, since it can be used as the subject in both collective and distributive sentences – and vary the reading based solely on the adverb. Again, I anticipate being able to find a significant difference between collective and distributive conditions, though it is possible that the effect could be attenuated by sie’s default interpretation leading to a collective sentence (Kaup et al., 2002).

Finally, a central question that I have not addressed is what it means for a mental representation to be plural. In formal semantics, the focus is on specifying the truth conditions for a sentence, giving an explicit logic statement that describes how the world would have to be for the sentence to be true. Formal semantics, then, is concerned with the relation of language to the world, and plurality is simply taken to be a property of how objects and events can combine that is reflected in language. Formal treatments like Link (1983) and Landman (1996) are, in effect, characterizations of how to derive truth conditions that correspond with the structure of things and events in the world. This type of modeling is instructive and captures important aspects of how plural linguistic terms seem to interface with objects and events in the world. But it does not address the issue of how we represent plural linguistic expressions in our minds. Specifically, what does it mean for an event representation to be plural? In distributive sentences,
for example, are there actually multiple sub-event tokens with very specific information about participants in each, or is there only one fully specified event representation and a some sort of marker plural feature that indicates that there is simply more than one of the fully specified representation? The present study cannot answer these questions directly, but by adding to our understanding of the processing of plurals, it moves us closer to an answer. More studies of the effects of plural linguistic items and of the nature of mental representations in general will be necessary to fully understand these phenomena.

Davidson argued in 1967 for an extra slot in predicates for an event argument, and events have proven to be a valuable tool in formal semantic analyses of a variety linguistic phenomena ever since. The present study suggests that events are not only helpful in formal semantics: they play a central role in the understanding of sentences. This study has shown that the event representations people create on-line when reading collective sentences differ from the event representations for distributive sentences. Distributive event representations have a complex structure involving multiple sub-events with their own structure. An important use of language is to convey information about goings-on in the world around us. Linguistic encoding of these goings-on can specify very detailed and structured information about them, and this thesis suggests that the mental representations resulting from these encodings have a detailed structure of their own.
Zusammenfassung auf Deutsch


Das zu untersuchende Phänomen beruht auf die zwei Lesarten von Sätzen mit pluralen Subjekten wie in (3).

(3) Hans und Maria tragen eine Kiste.


Stand der Forschung

In dieser Arbeit betrachte ich Kollektivität und Distributivität aus zwei Blickwinkeln: von der Perspektive der formalen Semantik und von der experimentellen Psycholinguistik. Wie kollektive und distributive Sätze formal semantisch zu analysieren sind, ist ein viel diskutiertes Thema in der Semantik. In meiner Arbeit schließe ich mich an die formale Forschung an, die
annimmt, dass Ereignisse eine zentrale Rolle in semantische Analysen spielen (nach Davidson, 1967).


als eine mentale Repräsentation für ein singulares Nomen in distributiven Sätzen gibt, wohingegen es nur eine Repräsentation in kollektiven Sätzen gibt.

Da sie aber mit diesen Experimenten nicht ausschließen konnten, dass der Effekt eigentlich der Pluralität der Ereignissen in den distributiven Sätzen zuzuschreiben war, haben Patson und Warren eine neue Studie gemacht, um dies zu testen (Patson & Warren, 2011). Sie haben das gleiche Paradigma (1/2-Entscheidung) benutzt, aber diesmal haben die blau markierte Wortgruppen das Verb des Satzes enthalten, um zu testen, ob die implizite Pluralität der Ereignisse in distributiven Sätzen einen ähnlichen Effekt produzieren kann. Sie haben einen Effekt nur bei Sätzen gefunden, in denen das Subjekt aus zwei mit "und" verbundenen NPs bestanden hat, d.h., die Referenten in dem pluralen Subjekt wurden separate eingeführt.


**Durchgeführtes Experiment**

Das Material hatte die folgende Form. Ein Hauptsatz führt zwei Individuen ein, die eine Handlung in Bezug auf ein direktes Objekt ausführen. Dann wird das direkte Objekt in einem Nebensatz modifiziert, indem die im Hauptsatz eingeführten Individuen entweder kollektiv oder distributiv etwas mit dem Objekt machen. Ein Beispiel:

(4) a. Die Schüler Hans und Maria haben einen neuen Schlitten bekommen, auf dem beide nacheinander den Hügel herunter rodeln.

b. Die Schüler Hans und Maria haben einen neuen Schlitten bekommen, auf dem sie zusammen den Hügel herunter rodeln.

In (4-a), wird die Handlung im Nebensatz separat durchgeführt, was „beide nacheinander“ betont. Aber in (4-b) wird die Handlung gemeinsam durchgeführt, was durch „sie zusammen“ klar gemacht wird.


**Ergebnisse**

Die Ergebnisse wurden mit einem gemischten Modell analysiert (Baayen, 2008; Baayen et al., 2008). Der wichtigste signifikante Effekt war der Einfluss von Lesart (kollektiv oder distributiv). Die Reaktionszeiten für die distributive Bedingung war significant länger als die für die kollektive Bedingung. Dies spricht dafür, dass sich die mentale Repräsentationen von kollektiven und distributiven Sätzen darin unterscheiden, dass distributive Sätze mehr als eine Ereignisrepräsentation haben, während kollektive Sätze nur ein Ereignis haben.

Allgemein betrachtet sprechen diese Ergebnisse für die bedeutende Rolle von Ereignissen in Sprachverstehen. Die Ereignisrepräsentationen, die wir bei Sprachverstehen bauen, können eine komplexe innere Struktur haben, die die durch Sprache vermittelten Strukturen in der Welt widerspiegeln.
Bibliography


Bates, D., Maechler, M., & Bolker, B. (2012). lme4: Linear mixed-effects models using S4 classes (R package version 0.999999-0 ed.) [Computer software manual]. Retrieved from http://CRAN.R-project.org/package=lme4


Appendix

Test items

The phrases in braces indicate the location of the manipulation of reading: 

sie zusammen for collective, beide nacheinander for distributive.

1. Die Sechstklässler Tim und Julian haben ein hölzernes Floß gebaut, auf dem {sie zusammen/beide nacheinander} über den Fluss fahren.
   The sixth graders Tim and Julian built a wooden raft on which they ride across the river together/on which both ride across the river one after the other.

2. Die Jungen Finn und Martin haben eine neue Holzeisenbahn bekommen, mit der {sie zusammen/beide nacheinander} vergnügt spielen.
   The boys Finn and Martin received a new wooden train set with which they play happily together/with which both play happily one after the other.

3. Die Schwestern Charlotte und Anna haben eine schöne Puppe bekommen, mit der {sie zusammen/beide nacheinander} kurz spielen.
   The sisters Charlotte and Anna received a beautiful doll with which they play for a short time together/with which both play for a short time one after the other.

4. Die Geschwister Dominik und Emilia haben einen jungen Welpen bekommen, den {sie zusammen/beide nacheinander} im Park ausführen.
   The siblings Dominik and Emilia received a young puppy which they walk in the park together/which both walk in the park one after the other.
   The flight attendants Angela and Paul fetched a serving cart which they bring through the aisle together/which both bring through the aisle one after the other.

6. *Die Schülerinnen Emma und Hanna haben ein einfaches Puzzle gekauft, das {sie zusammen/beide nacheinander} schnell fertigstellen.*
   The school girls Emma and Hanna bought a simple puzzle which they quickly assemble together/which both quickly assemble one after the other.

7. *Die Gymnasiasten Leon und Lukas haben eine kleine Rakete gebastelt, die {sie zusammen/beide nacheinander} aufgeregt abschießen.*
   The high schoolers Leon and Lukas made a model rocket which they shoot off excitedly together/which both shoot off excitedly one after the other.

8. *Die Hobbysegler Jakob und Moritz haben ein kleines Segelboot gemietet, in dem {sie zusammen/beide nacheinander} um den Hafen segeln.*
   The amateur sailors Jakob and Moritz rented a small sailboat which they sail around the harbor together/which both sail around the harbor one after the other.

   The farmer’s children Tobias and Jonas found a large tractor tire which they roll down the hill together/which both roll down the hill one after the other.

10. *Die Studierenden Philipp und Maria haben einen kleinen Holzkohlegrill angezündet, auf den {sie zusammen/beide nacheinander} gut aufpassen.*
    The students Philipp and Maria started a small charcoal grill which they tend well together/which both tend well one after the other.

11. *Die Bankräuber Lars und Henry haben eine große Bank ausgesucht, die {sie zusammen/beide nacheinander} gründlich auskundschaften.*
The bank robbers Lars and Henry sought out a large bank which they thoroughly spy out together/which both thoroughly spy out one after the other.

   The amateur pilots Hans and Fritz built a light glider which the fly over the lake together/which both fly over the lake one after the other.

13. *Die Unternehmer Mark und Annette haben einen angesehenen Rechtsanwalt engagiert, den {sie zusammen/beide nacheinander} im Konferenzraum treffen.*
   The entrepreneurs Mark and Annette hired a respected attorney who they meet in the conference room together/who both meet in the conference room one after the other.

14. *Die Freundinnen Lena und Sabine haben eine bequeme Hängematte aufgebaut, in der {sie zusammen/beide nacheinander} lange schaukeln.*
   The friends Lena and Sabrina set up a comfortable hammock in which the swing for a long time together/in which both swing for a long time one after the other.

15. *Die Umzugshelfer Erik und Jan haben eine schwere Kiste gepackt, die {sie zusammen/beide nacheinander} kurz tragen.*
   The movers Erik and Jan packed a heavy box which they carry for a short distance together/which both carry for a short distance one after the other.

16. *Die Schüler Mia und Benjamin haben einen neuen Schlitten bekommen, auf dem {sie zusammen/beide nacheinander} den Berg herunter rodeln.*
   The school children Mia and Benjamin received a sled on which they sled down the mountain together/on which both sled down the mountain one after the other.

**Filler items and comprehension questions**

Filler items that contained the mismatched names for the first nine participants are marked with an asterisk.
1. *Die Geburtstagskinder Andrea und Elias haben ein teures Geschenk bekommen, das sie nicht mögen.*
The birthday kids Andrea and Elias received an expensive gift that they don’t like.
Question: *Gefällt Andrea und Elias das Geschenk?*
Do Andrea and Elias like the gift?

The researchers Julia and Georg discovered an unknown butterfly that lives in the jungle.
Question: *Haben Julia und Georg einen Schmetterling entdeckt?*
Did Julia and Georg discover a butterfly?

3. *Die Fußballspielerinnen Karoline und Sandra haben mit einem neuen Trainer trainiert, den sie sehr mögen.*
The soccer players Karoline and Sandra trained with a new coach who they like very much.
Original question: *Mögen Andre und Sandra den neuen Trainer?*
Do Andre and Sandra like the new coach?
Corrected question: *Mögen Karoline und Sandra den neuen Trainer?*
Do Karoline and Sandra like the new coach?

4. *Die Klavierspieler Alexander und Ulrike haben eine klassische Sonate eingeübt, die sehr schwierig ist.*
The pianists Alexander and Ulrike learned a classical sonata which is very difficult.
Question: *Spielen Alexander und Ulrike Klavier?*
Do Alexander and Ulrike play piano?

5. *Die Musikfreunde Oliver und Martina sind zu einem Jazz-Konzert gegangen, das fast ausverkauft war.*
The music enthusiasts Oliver and Martina went to a jazz concert that was almost sold out.
Question: *Gab es noch Tickets für das Konzert?*
Were there still tickets to the concert?

The epicures Rainer and Gudrun opened a fine wine which they drink with friends.
Question: Haben Rainer und Gudrun den Wein getrunken?
Did Rainer and Gudrun drink the wine.

7. Die Studentinnen Tanja und Katrin haben ein neues Kartenspiel gespielt, das komplizierte Spielregeln hat.
The students Tanja and Katrin played a new card game that has complicated rules.
Question: Haben Tanja und Katrin ein leichtes Kartenspiel gespielt?
Did Tanja and Katrin play an easy card game?

8. Die Förster Michaela und Frank haben ein kleines Eichhörnchen gesehen, das in einem Ahornbaum wohnt.
The foresters Michaela and Frank saw a small squirrel that lives in a tree.
Question: Haben Michaela und Frank ein Eichhörnchen gesehen?
Did Michaela and Frank see a squirrel?

The roommates Roberta and Alexandra planned a joint birthday party to which they invited their friends.
Original question: Haben Robert und Alexandra zwei getrennte Geburtstagspartys geplant?
Did Robert and Alexandra plan two separate birthday parties?
Corrected question: Haben Roberta und Alexandra zwei getrennte Geburtstagspartys geplant?
Did Roberta and Alexandra plan two separate birthday parties?

The siblings Sofia and Kai made a small paper ship which the let float in a brook.
Question: Sind Sofia und Kai verwandt?
Are Sofia and Kai related?

The gardeners Torsten and Katharina planted a rosebush which they water daily.

Question: *Gießen Torsten und Katharina den Rosenstock alle zwei Tage?*

Do Torsten and Katharina water the rosebush every other day?

12. *Die Akademiker Heiko und Hannes haben ein philosophisches Buch gelesen, das sie im Café diskutieren.*

The academics Heiko and Hannes read a philosophical book which they discuss in a café.

Question: *Haben Heiko und Hannes ein Café besucht?*

Did Heiko and Hannes visit a café?


The grandparents Astrid and Olaf bought a cute teddy bear which they give to their granddaughter.

Question: *Haben Astrid und Olaf den Plüschbären gewonnen?*

Did Astrid and Olaf win the teddy bear?


The cousins Katja and Magda received a new dollhouse with which they like to play.

Question: *Haben Katja und Magda das Puppenhaus selbst gekauft?*

Did Katja and Magda buy the dollhouse themselves?

15. *Die Innenarchitektinnen Manuela und Birgit haben eine große Wohnung eingerichtet, die in einem schicken Neubau ist.*

The interior designers Manuela and Birgit furnished a large apartment which is in a posh new development.

Question: *Haben Manuela und Birgit eine kleine Wohnung eingerichtet?*

Did Manuela and Birgit furnish a small apartment?


The parents Sven and Paula bought a modern stroller which is very light.
Question: Ist der Kinderwagen modern?
Is the stroller modern?

17. Die Dokumentarfilmer Susanne und Thomas haben einen langen Film gedreht, der sehr kontrovers ist.
The documentarians Susanne and Thomas shot a long film which is very controversial.

Question: Haben Susanne und Thomas einen kurzen Film gedreht?
Did Susanne and Thomas shoot a short film?

Instructions


Wenn ein Satzteil in gelb geschrieben ist, dann gib so schnell wie möglich an, ob es sich um ein Wort oder um zwei Wörter handelt. Drücke dazu entweder die 1-Taste (für ein Wort) oder die 2-Taste (für zwei Wörter) auf der rechten Eingabegerät.

Wie angekündigt, gibt es nach manchen Sätzen eine Verständnisfrage, die sich auf den Inhalt des jeweiligen Satzes bezieht. Wenn Du denkst, dass die Frage mit Ja zu beantworten ist, dann drücke bitte die Ja-Taste auf der linken Eingabegerät. Wenn Du denkst, dass die Frage mit Nein zu beantworten ist, dann drücke bitte die Nein-Taste.


Wenn Du jetzt Fragen hast, dann wende Dich an den Versuchsleiter. Während des Experiments dürfen keine Fragen gestellt werden.

Thank you for taking part in this experiment! In this experiment, you will read a series of sentences. The sentences will not be presented as wholes, rather they will be presented in parts consisting of one to two words. Your task is, first, to read the sentences attentively so that you understand them. After some sentences, there will be a comprehension question. There is also another task. In every sentence, there will be a part in which the word or words are printed in yellow. You should then enter as fast as possible whether that sentence part contains one or two words.

Before every sentence, a cross will be presented on the screen. Please press the “next” button on the button box on your left as soon as you are ready to read the sentence. Then, the first sentence part will appear. When you have read this one, please press the “next” button again. Then, the next sentence part will appear. So, always press the “next” button to get to the next sentence part.

If a sentence part is presented in yellow, then enter as quickly as possible whether there are one or two words. To do that, press the “1” (for one word) or the “2” button (for two words) on the right button box.

As mentioned above, there is a comprehension question after some sentences that refers to the content of the preceding sentence. If you think the question should be answered with a yes, then please press the “Yes” button on the left button box. If you thing the question should be answered with a
no, the please press the “No” button.

Please read each sentence at your usual reading speed and so that you understand it. Make your decision about the number of words (one or two) in the yellow sentence part quickly but carefully. Please do not take breaks in the middle of a sentence. If you need a break, you can do that after a sentence before beginning the next one.

Before the actual experiment begins, there is a short practice round that is meant to illustrate to you your task in the experiment. In the practice round, there are four sentences that you should work through according to the procedure described here.

If you have questions, please contact the examiner. During the experiment, you may not ask any questions.
Selbstständigkeitserklärung

Humboldt-Universität zu Berlin
Philosophische Fakultät II
Garrett Smith
Matrikelnummer: 526025

Eidesstattliche Erklärung zur Masterarbeit

Ich erkläre ausdrücklich, dass es sich bei der von mir eingereichten schriftlichen Arbeit mit dem Titel „Event representations in collective and distributive readings: an on-line study“ um eine von mir erstmalig, selbstständig und ohne fremde Hilfe verfasste Arbeit handelt.


Unterschrift:
Datum: 2. November 2013