Interpreting Disjunction under Deontic Modals: An Experimental Investigation

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Abstract

Disjunction under a deontic possibility modal (i.e., *may/or* sentences) or a deontic necessity modal (i.e., *must/or* sentences) may give rise to three types of inferences: free choice inferences (i.e., the inferences which imply that the options indicated by each of the individual disjuncts are permitted), exhaustivity inferences (i.e., the inferences which imply that the options that are not indicated by the individual disjuncts are not permitted), and exclusive *or* inferences (i.e., the inferences which imply that no more than one option indicated by the individual disjuncts is permitted at the same time). There is an ongoing debate among recent theoretical studies (e.g. Fox, 2007; Geurts, 2005; Simons, 2004) regarding whether these inferences are available and how they are derived for each of the above mentioned constructions. In experiments, the availability of the inferences can be reflected by derivation rates, while the derivation mechanism of the inferences can be reflected by processing time-courses. Based on this, an experiment involved with a picture-sentence binary judgment task was conducted in this study. It examined the the derivation rates and processing time-courses of the three types of inferences drawn from *may/or* sentences and *must/or* sentences. The results of the experiment indicate that in the processing of *may/or* sentences and *must/or* sentences, free choice inferences were similarly derived around 90% of the times, and the derivation of them was not accompanied by an increase of processing time (i.e., the derivation of them did not take a longer time than the derivation of logical meanings). The results further indicate that exhaustivity inferences and exclusive *or* inferences were derived around 15% and 30% of the times for *may/or* sentences respectively, and the derivation of them was accompanied by an increase of processing time. Compared with this, exhaustivity inferences and exclusive *or* inferences were derived around 98% and 94% of the times for *must/or* sentences respectively, and the derivation of them was not accompanied by additional processing time. It seems that under the current experimental paradigm, *may/or* sentences were interpreted as expressions that grant weak permission, while *must/or* sentences were interpreted as expressions that grant strong permission. The results seem to be consistent with Simons's (2004) account to a large extent.

Key words: disjunction, deontic modals, permission, free choice inferences, exhaustivity inferences, exclusive *or* inferences

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1 Introduction

The focus of this study is to understand how disjunction is interpreted under deontic modals. I focus my discussions on two types of sentences: the sentences with disjunction embedded under deontic possibility modals such as *may* (i.e., *may/or* sentences), and the sentences with disjunction embedded under deontic necessity modals such as *must* (i.e., *must/or* sentences). Let's start from phenomena to see what I aim to investigate and why I want to investigate them.

(1) a. context: Jayden's mom regularly cleans the house on Sundays. When Jayden came back home on this Sunday afternoon, **his mom still haven't cleaned the dustbins, the windows and the kitchen**. So Jayden asked his mom whether there was anything that he could help with.
b. Jayden: "what can I help with?"
c. Jayden's mom: "**you may clean the dustbins or the windows.**"
d. Jayden's mom: "**you must clean the dustbins or the windows.**"

Throughout the study, I focus on discussing the interpretation of *may/or* sentences such as (1c) and the interpretation of *must/or* sentences such as (1d). For these two types of sentences, I want to know whether the following types of inferences can be derived.

(2) a. **free choice inferences**: you may clean the dustbins.
you may clean the windows.
b. **exhaustivity inference**: you may not clean the kitchen.
c. **exclusive *or* inference**: you may not clean both the dustbins and the windows.

Generally, I want to know three things about *may/or* sentences and *must/or* sentences. First, I want to know whether it is the case that the options indicated by each of the individual disjuncts are permitted. If it is the case, free choice inferences such as (2a) should be derived. Second, I want to know whether it is the case that the options that are not indicated by the individual disjuncts are not permitted. If it is the case, exhaustivity inferences such as (2b) should be derived. Third, I want to know whether it is the case that more than one option indicated by the individual disjuncts is not permitted at the same time. If it is the case, exclusive *or* inferences such as (2c) should be derived.

May/or sentences and *must/or* sentences are intensively discussed by recent theoretical studies (e.g. Fox, 2007; Geurts, 2005; Simons, 2004, etc.) primarily because of the free choice inferences triggered by them. Free choice inferences are special because they cannot be explained by standard semantics. In addition, Sauerland's (2004) account, which is widely adopted as the standard Neo-Gricean reasoning for implicatures drawn from disjunction, can only predict the free choice inferences drawn from *must/or* sentences, but not those drawn from *may/or* sentences. In order to provide an uniformed account for free choice inferences drawn from *may/or* sentences and *must/or* sentences, in general, two types of accounts are developed. One type of accounts (e.g., Fox, 2007; Alonso-Ovalle, 2006) analyzes free choice inferences as a special type of scalar implicatures. I name this type of accounts as *scalar implicature* accounts throughout the study. The other type of accounts (e.g., Geurts, 2005; Simons, 2004; etc.) analyzes free choice inferences as parts of logical meanings of *may/or* sentences and *must/or* sentences. I name this type of accounts as semantic accounts throughout the study. Different accounts are different from each other not only in predicting the derivation mechanism of scalar implicatures, but also in predicting the availability of exhaustivity inferences and exclusive *or* inferences. For example, while Geurts (2005) claims that exhaustivity inferences should be available for both *may/or* sentences and *must/or* sentences, Simons (2004) claims that exhaustivity inferences should only be available for *must/or* sentences but not for *may/or* sentences. In addition, while Geurts (2005) and Simons (2004) claim that exclusive *or* inferences should be available for both *may/or* sentences and *must/or* sentences, Fox (2007) and Alonso-Ovalle (2006) claim that exclusive *or* inferences should only be available for *may/or* sentences, but not for *must/or* sentences. According to Kaufmann (2016) and Barker (2010), sentences with disjunction embedded under deontic modals express **strong permission** if both exhaustivity inferences and exclusive *or* inferences are derived. Conversely, the same type of sentences expresses **weak permission** if both exhaustivity inferences and exclusive *or* inferences are not derived. More specifically, for either the *may/or* sentence in (1c) or the *must/or* sentence in (1d), if (2b) and (2c) together with (2a) are derived, the sentence expresses strong permission. By contrast, if the only inference that is derived is (2a), then the sentence expresses weak permission.

Based on the above mentioned discrepancies in theoretical studies, I designed an experiment to examine the derivation rates and processing time-courses of the three types of inferences associated with *may/or* sentences and *must/or* sentences. The experiment may help us understand the processing of disjunction under deontic modals in three aspects. First, it provides novel experimental data on the processing of disjunction under deontic necessity modals. Second, it provides novel data on the processing of exhaustivity inferences and exclusive *or* inferences drawn from disjunction embedded under deontic modals. Third, it enriches our knowledge about the processing of free choice inferences. In literature, there are only a few experimental studies (e.g. van Tiel, 2012; Chemla, 2009) that investigate the free choice inferences drawn from disjunction embedded under deontic possibility modals. Most of them only investigate the derivation rates of free choice inferences, and only one of them (i.e., Chemla & Bott, 2014) reports the processing time of free choice inferences. Thus, I think it is still very valuable to see whether previous results can be replicated under a different experimental paradigm (i.e., a picture-sentence judgment task).

The arrangement of the thesis is as follows. In Section 2, I review the theoretical studies. In Section 3, I review the relevant experimental studies. In Section 4, I propose research questions and hypotheses based on the literature I review. In section 5, I present the experimental design. In section 6, I report the results of the experiment. In section 7, I discuss the experimental results.

2 Review of Theoretical Studies

In this section, I first show why standard semantics and the standard Neo-Gricean account cannot account for free choice inferences drawn from *may/or* sentences (Section 2.1). Then I review *scalar implicature* accounts (Section 2.2) and semantic accounts (Section 2.3), which provide uniformed explanations for free choice inferences drawn from *may/or* sentences and *must/or* sentences.

2.1 *May/or* sentences and *Must/or* Sentences under Classical Accounts

Under the Boolean analysis, the disjunctive coordinator, *or*, is an inclusive *or* (symbolized as $\vee$). The truth value table of *or* is given below:

Table 2.1 Truth Value Table of *OR*

A	B	A $\vee$ B
1	0	1
0	1	1
1	1	1
0	0	0

Note: "1" represents *true*; "0" represents *false*.

According to Table 2.1, A $\vee$ B is true if at least one among A and B is true.

Under the standard semantics for deontic modals, the deontic possibility modal *may* (symbolized as ◊) and the deontic necessity modal *must* (symbolized as □) are analyzed as follows:

(3) a. ◊ [[A]] = 1 at w^* iff $\exists\, w \in ACC_{d,w^*}$, s.t. $w \in$ [[A]]

b. □ [[A]] = 1 at w^* iff $\forall\, w \in ACC_{d,\, w^*}$, s.t. $w \in$ [[A]]

Note: w^* denotes the set of worlds of evaluation. $ACC_{d,\, w^*}$ denotes a set of worlds that are deontically accessible from w^*.

(See Simons, 2004, p4 & p6)

(3a) says that *may* [[A]] is true if and only if there exists at least one world that is deontically accessible from the set of world of evaluation, such that the proposition, A, is true in this world. (3b) says that *must* [[A]] is true if and only if in all worlds that are deontically accessible from the set of worlds of evaluation, the proposition, A, is true.

Let's see what is the logical meaning of (4a) and (5a) given the standard semantics for the disjunctive coordinator and deontic modals.

(4) a. Mary may eat the apple or the banana.

b. ◊ [[apple $\vee$ banana]] = 1 at w^* iff $\exists\, w \in ACC_{d,w^*}$, s.t. $w \in$ [[apple $\vee$ banana]]

(4b) is the logical meaning of (4a). It says that (4a) is true if and only if Mary eats at least one of the apple and the banana in at least one of the worlds that are deontically accessible. It entails a minimum requirement that there should exist one deontically accessible world in which Mary eats one of the apple and the banana. If this requirement is not satisfied, (4a) will be false. Based on this, in the situation in which Mary is only granted permission to eat the apple but not the banana, (4a) is true. Alternatively, in the situation in which Mary is granted permission to eat the apple and permission to eat the banana (i.e., a free choice inference), (4a) is also true. From this, we can see that the logical meaning of (4a) is entailed by the free choice inference, so it conveys a meaning much weaker than the free choice inference.

(5) a. Mary must eat the apple or the banana.

b. $\Box$ [apple $\vee$ banana] = 1 at w^* iff $\forall w \in \text{ACC}_{d,w^*}$, s.t. $w \in$ [[apple $\vee$ banana]]

(5b) is the logical meaning of (5a). It says that (5a) is true if and only if in all worlds that are deontically accessible, Mary eats at least one of the apple and the banana. According to this, (5a) can be true under several situations. If Mary only eats the apple in all deontically accessible worlds, i.e., if Mary is under the obligation to the apple, (5a) is true. Similarly, if Mary only eats the banana in all deontically accessible worlds, i.e., if Mary is under the obligation to eat the banana, (5a) is true. In addition, if Mary eats the apple in some of the deontically accessible worlds but eats the banana in the rest of the deontically accessible worlds (i.e., a free choice inference), (5a) is also true. Therefore, similar as (4b), (5b) is compatible with the free choice inference, but it is also weaker than the free choice inference.

Now let's see what implicatures can be drawn from (4a) and (5a) based on Sauerland's (2004) Neo-Gricean account[1]. (4a) is repeated as (6a), and (5a) is repeated as (7a).

(6) a. Mary may eat the apple or the banana.

b. Alt(6a) = $\{\Diamond (a \vee b), \Diamond (a\, \boldsymbol{L}\, b), \Diamond (a\, \boldsymbol{R}\, b), \Diamond (a \wedge b), \Box (a \vee b), \Box (a\, \boldsymbol{L}\, \text{b}), \Box (a\, \boldsymbol{R}\, b), \Box(a \wedge b)\}$

$= \{\Diamond (a \vee b), \Diamond a, \Diamond b, \Diamond (a \wedge b), \Box (a \vee b), \Box a, \Box b, \Box (a \wedge b)\}$[2]

c. Maxim of Quality: the speaker should only say what he/she believes to be true.

Bs ($\Diamond (a \vee b)$)

d. Maxim of Quantity:

Since $\Diamond a$, $\Diamond b$, $\Diamond (a \wedge b)$, $\Box (a \vee b)$, $\Box a$, $\Box b$, and $\Box (a \wedge b)$ are more informative than $\Diamond (a \vee b)$[3], if the speaker believes any of them to be true, he/she should have said it.

Primary Implicatures:

$\neg$ Bs ($\Diamond a$) & $\neg$ Bs ($\Diamond b$)[4], the rest,

$\neg$ Bs ($\Diamond (a \wedge b)$) & $\neg$ Bs ($\Box (a \vee b)$) & $\neg$ Bs ($\Box a$) & $\neg$ Bs ($\Box b$) & $\neg$ Bs ($\Box(a \wedge b)$) follow:

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1 A review of Sauerland's account can be found in Appendix.

2 Notes on abbreviations: $\Diamond$: *may*; $\Box$: *must*; *a*: the apple; *b*: the banana.

Notes on alternatives: there are two scalar items in $\Diamond (a \vee b)$: $\Diamond$ (*may*) and $\vee$ (*or*). I use Horn-scale for $\Diamond$ (see Horn (1973)). Horn-scale ($\Diamond$) = {$\Diamond$ (*may*), $\Box$ (*must*)}. I use Sauerland's scale for $\vee$ (*or*). Sauerland-scale ($\vee$) = {$\vee$, $\boldsymbol{L}$, $\boldsymbol{R}$, $\wedge$}. In order to obtain all formally defined alternatives for $\Diamond (a \vee b)$, we need to replace both $\Diamond$ and $\vee$ with their scalar alternatives. As a result, we get the list in (6b).

3 $\Diamond a \Rightarrow \Diamond (a \vee b)$, $\Diamond b \Rightarrow \Diamond (a \vee b)$, $\Diamond (a \wedge b) \Rightarrow \Diamond (a \vee b)$, $\Box (\text{a} \vee \text{b}) \Rightarrow \Diamond (a \vee b)$, $\Box a \Rightarrow \Diamond (a \vee b)$, $\Box b \Rightarrow \Diamond (a \vee b)$, $\Box (a \wedge b) \Rightarrow \Diamond (a \vee b)$. Since $\Diamond a$, $\Diamond b$, $\Diamond (a \wedge b)$, $\Box a$, $\Box$ b, and $\Box (a \wedge b)$ entail $\Diamond (a \vee b)$, they are logically stronger and more informative than $\Diamond (a \vee b)$.

4 An explanation of why $\neg$ Bs ($\Diamond a$) and $\neg$ Bs ($\Diamond b$) cannot be strengthened to SIs:

If we strengthen both $\neg$ Bs ($\Diamond a$) and $\neg$ Bs ($\Diamond b$), then we will get Bs ($\neg \Diamond a$) and Bs ($\neg \Diamond b$). If Bs ($\neg \Diamond a$) and Bs ($\neg \Diamond b$), then Bs ($\neg \Diamond (a \vee b)$). However, based on the maxim of quality, Bs ($\Diamond (a \vee b)$). So strengthening both $\neg$ Bs ($\Diamond a$) and $\neg$ Bs ($\Diamond b$) leads to a contradictory result.

If we only strengthen one of $\neg$ Bs ($\Diamond a$) and $\neg$ Bs ($\Diamond b$), then we will get either Bs ($\neg \Diamond a$) or Bs ($\neg \Diamond b$) as a SI. Based on the maxim of quality, Bs ($\Diamond (a \vee b)$). Assume that Bs ($\neg \Diamond a$) is derived as a SI. If we want to guarantee that Bs ($\Diamond (a \vee b)$) and Bs ($\neg \Diamond a$) are valid at the same time, we need one additional inference that Bs ($\Diamond b$). However, under the given circumstance, we can only derive $\neg$ Bs ($\Diamond b$), which is not consistent with Bs ($\Diamond b$).

As a result, the only option left is to derive two ignorance inferences: $\neg$ Bs ($\Diamond a$) and $\neg$ Bs ($\Diamond b$).

e. Opinionated Speaker:

The speaker by default believes stronger alternatives are false if they are not contradictory with the speaker's other beliefs.

<u>Secondary Implicatures:</u>

Bs ($\neg\Diamond (a \wedge b)$) & Bs ($\neg\Box(a \vee b)$) & Bs ($\neg\Box\, a$) & Bs ($\neg\Box\, b$) & Bs ($\neg\Box(a \wedge b)$)

f. strengthened meaning = (6c) & PIs in (6d) & SIs in (6e)

Bs ($\Diamond (a \vee b)$) & $\neg$Bs ($\Diamond\, a$) & $\neg$Bs ($\Diamond\, b$) & Bs ($\neg\Diamond (a \wedge b)$) & Bs ($\neg\Box(a \vee b)$) & Bs ($\neg\Box\, a$) & Bs ($\neg\Box\, b$) & Bs ($\neg\Box(a \wedge b)$)

Let's check what the implicatures imply. First, the scalar implicatures (also known as secondary implicatures), Bs ($\neg\Box(a \vee b)$), Bs ($\neg\Box\, a$), Bs ($\neg\Box\, b$) and Bs ($\neg\Box(a \wedge b)$), imply that the speaker believes that Mary is not under obligation to eat at least one of the apple and the banana, that she is not under obligation to eat the apple, that she is not under obligation to eat the banana, that she is also not under obligation to eat both fruits. Second, the scalar implicature, Bs ($\neg\Diamond (a \wedge b)$), implies that the speaker believes that Mary is not allowed to eat both fruits. Third, the ignorance inferences (also known as primary implicatures), $\neg$Bs ($\Diamond\, a$) and $\neg$Bs ($\Diamond\, b$), imply that the speaker is not sure whether Mary is allowed to eat the apple and he/she is also not sure whether Mary is allowed to eat the banana. Combining all those implicatures, we can conclude that Mary is allowed but not required to eat either the apple or the banana, but the speaker is not sure which one is actually allowed. Please notice that this strengthened meaning is incompatible with the free choice inference of (6a), which indicates that the speaker is certain that the apple is a permitted option and the banana is also a permitted option.

(7) a. Mary must eat the apple or the banana.

b. Alt (7a) = {$\Box (a \vee b)$, $\Box (a\, \boldsymbol{L}\, b)$, $\Box (a\, \boldsymbol{R}\, b)$, $\Box (a \wedge b)$} = {$\Box (a \vee b)$, $\Box\, a$, $\Box\, b$, $\Box (a \wedge b)$}

c. Bs ($\Box (a \vee b)$) (the maxim of quality)

d. Primary Implicatures: (the maxim of quantity)

$\neg$Bs ($\Box\, a$) & $\neg$Bs ($\Box\, b$) & $\neg$Bs ($\Box(a \wedge b)$), all of which follow:

e. Secondary Implicatures: (opinionated speaker)

Bs ($\neg\Box\, a$) & Bs ($\neg\Box\, b$) & Bs ($\neg\Box(a \wedge b)$)

f. Strengthened meaning = (7c) & SIs in (7e)

Bs ($\Box (a \vee b)$) & Bs ($\neg\Box\, a$) & Bs ($\neg\Box\, b$) & Bs ($\neg\Box(a \wedge b)$)

Notes: $\neg\Box\, a = \Diamond\neg a$; $\neg\Box\, b = \Diamond\neg b$; $\neg\Box(a \wedge b) = \Diamond\neg(\mathrm{a} \wedge \mathrm{b})$;

But, $\Diamond\neg a \neq \neg\Diamond\, a$; $\Diamond\neg b \neq \neg\Diamond\, b$; $\Diamond\neg(a \wedge b) \neq \neg\Diamond(a \wedge b)$[5]

All alternatives listed in (7b), except for $\Box$ (a $\vee$ b), are stronger than (7a). The negation of all these alternatives is not contradictory with (7c). Thus, we can safely assume that the speaker by default does not believe any of these alternatives to be true. As a result, we get three secondary implicatures in (7e), which indicate that the speaker believes that Mary does not eat the apple in all deontically accessible worlds (i.e., Bs ($\neg\Box\, a$)), that she does not eat the banana in all deontically accessible worlds (i.e., Bs ($\neg\Box\, b$)) and that she does not eat both the apple and the banana in all deontically accessbile worlds (i.e., Bs ($\neg\Box\, (a \wedge b)$)). To make it

[5] More details about the modal logic can be found in Mastop (2012).

simpler, (7e) implies that the speaker believes that Mary doesn't have to eat the apple, that she doesn't have to eat the banana, and that she doesn't have to eat the apple and the banana. Combining (7e) with (7c), we can conclude that Mary is allowed to eat the apple, that she is allowed to eat the banana, and that she is allowed to eat both the apple and the banana. Here, the free choice inference is successfully predicted.

To sum up, intuitively, when interpreting *may/or* sentences and *must/or* sentences, free choice inferences should be computed. However, standard semantics does not provide an explanation for free choice inferences, and the standard Neo-Gricean reasoning can only account for free choice inferences drawn from *must/or* sentences.

So now the issue is whether there is a way to uniformly predict free choice inferences drawn from *may/or* sentences and *must/or* sentences? Generally, there are two solutions for this issue. The first solution is to modify the standard Neo-Gricean account so that it can further explain free choice inferences associated with *may/or* sentences. This solution does not involve crucial changes in standard semantics. The second solution is to modify the semantics for deontic modals or the disjunctive coordinator or even both, so that free choice inferences can be explained as parts of truth conditions. In Section 2.2 and Section 2.3, we review two types of existing accounts of free choice inferences: *scalar implicature* accounts and semantic accounts.

Table 2.2 Two Types of Accounts

***scalar implicature* accounts**	Fox (2007), Alonso-Ovalle (2006)
semantic accounts	Zimmermann (2000), Geurts (2005), Simons (2004)

Please notice that except for the accounts we reviewed, there also are a few novel accounts on market, e.g. Barker (2010), Starr (2016), Franke (2011), etc. However, due to space limit, the detailed discussion of these accounts in light of the experimental data will have to be left for future research. In addition, most of these novel accounts only discuss *may/or* sentences but not *must/or* sentences. This is another reason why they are not reviewed in this study.

2.2 *May/or* sentences and *Must/or* Sentences under *Scalar Implicature* Accounts

The crucial problem in Sauerland's Neo-Gricean account is that it can only predict free choice inferences of *must/or* sentences but not those of *may/or* sentences. Under Sauerland's account, only ignorance inferences can be derived for *may/or* sentences and they are in contradiction with free choice inferences. More specifically, for sentences such as (8a), Sauerland only predicts the ignorance inferences in (8b), which imply that the speaker does not know whether Mary is allowed to eat the apple and that he/she does not know whether Mary is allowed to eat the banana. However, what we actually want to derive is the free choice inferences in (8c), which imply that the speaker does know that Mary is allowed to eat the apple and he/she does know that Mary is allowed to eat the banana.

(8) a. Mary may eat the apple or the banana.

b. ignorance inferences: $\neg$ Bs ($\Diamond$ *a*) & $\neg$ Bs ($\Diamond$ *b*)

c. free choice inferences: Bs ($\Diamond$ *a*) & Bs ($\Diamond$ b)

It seems that the ignorance inferences in (8b) are incompatible with the free choice inferences in (8c). Now the issue is that can we find a way to suppress ignorance inferences so that free choice inferences can be derived? Basically, there are two solutions. The first solution is to recursively negate speaker's beliefs on individual disjuncts. For example, if we negate Bs ($\Diamond$ *a*) once, we will get $\neg$ Bs ($\Diamond$ *a*). But if we further negate $\neg$ Bs ($\Diamond$ *a*), then we will get $\neg$ ($\neg$ Bs ($\Diamond$ *a*)), which is equivalent to Bs ($\Diamond$ *a*). This solution is explored by Fox (2007) (Section 2.2.1). The second solution is to prevent individual disjuncts from being negated and then further strengthen them to parts of the speaker's beliefs. This solution is developed by Alonso-Ovalle (2006) (Section 2.2.2). Of course, what I mention here is much more simplified than the actual frameworks proposed by Fox (2007) and Alonso-Ovalle (2006). I discuss all details in the rest parts of this section.

2.2.1 Recursive Exhaustification in Syntax

Fox (2007) proposes that implicatures of *may/or* sentences and *must/or* sentences are derived by recursively applying a covert exhaustification operator (*exh*) with the meaning similar as "only" at the syntactic level. The primary purpose of recursively applying the exhaustification operator is to eliminate as many ignorance inferences as possible.

The exhaustification operator introduces a function which negates all non-weaker alternatives that are innocently excludable. (9) shows how the set of innocently excludable alternatives is formed:

(9) a. $A \vee B$

b. Alt (9a) = $\{A \vee B, A, B, A \wedge B\}$

c. $Alt_{max1} = \{A, A \wedge B\}$

$Alt_{max2} = \{B, A \wedge B\}$

d. I-E = $\cap Alt_{max} = Alt_{max1} \cap Alt_{max2} = \{A, A \wedge B\} \cap \{B, A \wedge B\} = \{A \wedge B\}$

The first step is to compute all alternatives for (9a). Following Sauerland's algorithm, the disjunction, A *or* B, has four non-weaker alternatives: $A \vee B$, A, B and $A \wedge B$. The next step is to include as many alternatives in (9a) that can be negated together without being inconsistent with the truth condition of (9a) as possible into a set. This type of sets is known as the maximal sets. There are two ways to maximally negate the alternatives in (9b). If both A and $A \wedge B$ are negated, $A \vee B$ can still be true because B is not negated. Similarly, if both B and $A \wedge B$ are negated, $A \vee B$ can still be true because A is not negated. Thus, (9b) has two maximal sets, which are given in (9c). If an alternative is in every maximal set, it means that the negation of it is always consistent with the prejacent, so it can be excluded non-arbitrarily. Fox names this type of alternatives as innocently excludable alternatives. To obtain the set of innocently excludable alternatives, we only need to compute the intersection of all maximal sets. Here, the intersection of the maximal sets in (9c) only contains a member, $A \wedge B$. So $A \wedge B$ is the only innocently excludable alternative of (9a), and it is the only alternative that will be negated after the application of *exh*.

The exhaustification operator *exh* can be applied recursively to a sentence. For any sentence S with a set of alternatives Alt (S), if we apply *exh* once to it, we will get a sentence S^+ which has a stronger meaning than S. S^+ has a set of non-weaker alternatives Alt (S^+). If we apply *exh* again to S, then this time the exhaustification operator will operate over S^+ and Alt (S^+). As a result, we will get a sentence S^{++} which are stronger than S^+. S^{++} also has a set of non-weaker alternatives Alt (S^{++}). The similar process can occur again and again till no more ignorance inference can be eliminated.

Now let's see how Fox's recursive exhaustification predicts the inferences of *may/or* sentences such as (10).

(10) *Mario may choose the toy car or the Rubik's cube as his award.*

The logical meaning of (10) based on the standard semantics for *may* and *or* is:

(10a) $S = \Diamond (TC \vee RC^6)$

Fox follows Sauerland's algorithm of computing alternatives for disjunction. In addition, he further assumes that the set of alternatives is closed under disjunction, and *exh* can only operates over a closed set of alternatives. This is to say that except for the toy car and the Rubik's cube, nothing else exists in the set of worlds of evaluation. The set of alternatives of (10a) is given in (10b). And the set of innocently excludable alternatives of (10a) is given in (10d).

(10b) $Alt (S) = \{\Diamond (TC \vee RC), \Diamond TC, \Diamond RC, \Diamond (TC \wedge RC)\}$
(10c) $Alt_{max1} (S) = \{\Diamond TC, \Diamond (TC \wedge RC)\}$
$Alt_{max2} (S) = \{\Diamond RC, \Diamond (TC \wedge RC)\}$
(10d) $I\text{-}E (Alt (S)) = \{\Diamond (TC \wedge RC)\}$

If we apply *exh* once, the only innocently excludable alternative in (10d), $\Diamond (TC \wedge RC)$, will be excluded from (10b), and (10a) will be strengthened to (10e).

(10e) $S^+ = \Diamond (TC \vee RC) \ \& \neg \Diamond (TC \wedge RC)^7$

Please notice that based on the maxim of quantity, we will also derive two ignorance inferences in (10f), which indicate that the speaker is not sure whether choosing the toy car is permitted, and he/she is also not sure whether choosing the Rubik's cube is permitted.

(10f) $\neg Bs (\Diamond TC) \ \& \neg Bs (\Diamond RC)$

The ignorance inferences derived in (10f) might be implausible, thus they might be eliminated. So we apply *exh* once again. This time *exh* only operates over the strengthened sentence S^+ and its corresponding set of alternatives Alt (S^+).

(10g) $Alt (S^+) = \{\Diamond (TC \vee RC) \wedge \neg \Diamond (TC \wedge RC), \Diamond TC \wedge \neg \Diamond (TC \wedge RC), \Diamond RC \wedge \neg \Diamond (TC \wedge RC)^8\}$
$= \{\Diamond (TC \vee RC) \wedge \neg \Diamond (TC \wedge RC), \Diamond TC \wedge \neg \Diamond RC, \Diamond RC \wedge \neg \Diamond TC\}$

[6] Notes on abbreviations: TC: *the toy car*; RC: *the Rubik's cube*.
[7] Please notice that $\neg \Diamond (TC \wedge RC) \neq \neg (\Diamond TC \wedge \Diamond RC)$ (see Mastop, 2012)
[8] $\Diamond TC \wedge \neg \Diamond (TC \wedge RC) \Leftrightarrow \Diamond TC \wedge \neg \Diamond RC$; $\Diamond RC \wedge \neg \Diamond (TC \wedge RC) \Leftrightarrow \Diamond RC \wedge \neg \Diamond TC$.

(10h) Alt_{max} (S^+) = {◊ TC ∧ ¬◊ RC, ◊ RC ∧ ¬◊ TC}
(10i) I-E (Alt (S^+)) = {◊ TC ∧ ¬◊ RC, ◊ RC ∧ ¬◊ TC}

All alternatives in (10g), except for ◊ (TC ∨ RC) ∧ ¬◊ (TC ∧ RC), can be negated at the same time without contradicting the speaker's belief on (10e). So we exclude them and get a new strengthened sentence S^{++} in (10j).

(10j) S^{++} = ◊ (TC ∨ RC) & ¬◊ (TC ∧ RC) & ¬ (◊ TC ∧ ¬◊ RC) & ¬ (◊ RC ∧ ¬◊ TC)
= ◊ (TC ∨ RC) & ¬◊ (TC ∧ RC) & ◊ TC & ◊ RC[9]

Since no ignorance inference is generated this time, the recursive exhaustification stops at (10j). (10j) is the strengthened meaning of (10a), which implies that Mario is allowed to choose the toy car and he is also allowed to choose the Rubik cube, but he is not allowed to choose both at the same time[10].

(11) below illustrates how Fox predicts the inferences of *must/or* sentences.

(11) *Peter must clean the room or the dishes*.
a. S = □ (r ∨ d)[11]
b. Alt (S) = {□ (r ∨ d), □ r, □ d, □ (r ∧ d)}
Alt_{max} (S) = {□ r, □ d, □ (r ∧ d)}
I-E (Alt (S)) = {□ r, □ d, □ (r ∧ d)}
c. S^+ = □ (r ∨ d) & ¬□ r & ¬□ d & ¬□ (r ∧ d)

Fox's computation of implicatures drawn from *must/or* sentences is roughly the same as Sauerland's computation (see Section 2.1), so I will not explain it in details here. *Must/or* sentences do not involve the recursive exhaustification. The exhaustification operator *exh* only needs to apply once. The strengthened meaning (11c) suggests that Peter is allowed to clean the room, that he is allowed to clean the dishes, and that he is also allowed to clean both.

2.2.2 Recursive Pragmatic Reasoning

Different from Fox (2007) who proposes the recursive application of a syntactic operator *exh* to *may/or* sentences and *must/or* sentences, Alonso-Ovalle (2006) proposes a recursive pragmatic strengthening algorithm to predict the inferences drawn from *may/or* sentences and *must/or* sentences. Alonso-Ovalle (2006) adopts Hamblin's (1973) alternative semantics for

[9] ¬ (◊ TC ∧ ¬◊ RC) is true under three conditions: the condition in which ◊ TC ∧ ◊ RC is true, the condition in which (¬◊ TC) ∧ (¬◊ RC) is true, the condition in which(¬◊ TC) ∧ ◊ RC is true. Similarly, ¬ (◊ RC ∧ ¬◊ TC) also is true under three conditions: the condition in which ◊ RC ∧ ◊ TC is true, the condition in which(¬◊ RC) ∧ (¬◊ TC) is true, the condition in which (¬◊ RC) ∧ ◊ TC is true. Since all propositions in (10j) should be true at the same time, ◊ TC ∧ ◊ RC is the only option.

[10] Please notice that what is illustrated here is the standard recursive exhaustification proposed by Fox (2007). In this standard process, free choice implicatures drawn from *may/or* sentences are always accompanied by the derivation of exclusive *or* implicatures. Fox notices that it might be problematic because intuitively even without the accompanied derivation of exclusive *or* implicatures, free choice implicatures can still be drawn from *may/or* sentences. With regard to this issue, Fox suggests that each of the individual disjuncts can be focused so that each of them can be exhaustified separately. Under focused recursive exhaustification, ◊ (TC ∧ RC) is not counted as one of the alternatives of ◊ (TC ∨ RC). Due to this, the strengthened meaning is compatible with ◊ (TC ∧ RC).

[11] Notes on abbreviation: r: the room; d: the dishes.

disjunction, which analyzes disjunction as a set of propositions. Based on Hamlin (1973), the denotation of (12a) is (12b)[12] .

(12) a. Kate ate the apple or the banana.
b. {*eat* (*Kate*, *the_apple*), *eat* (*Kate*, *the_banana*)}

Since the alternative semantics is adopted to analyze disjunction, the disjunctive coordinator now can no longer be regarded as a scalar item. So it is necessary to come up with a new algorithm to compute the alternatives for disjunction. Alonso-Ovalle (2006) assumes that the set of alternatives of disjunction is activated by applying an existential closure operator ($\exists p$) under the scope of modals. The existential closure operator activates two functions which return two types of alternatives: conjunctive alternatives and sub-domain alternatives.

(13) a. Conjunctive Alternatives:
Assume that [[A]] = $\{a\}$ and [[B]] = $\{b\}$. The function, $Alt_{\cap}(\exists$ p([[A or B]])), returns $\{a, b, a \cap b\}$.
b. Sub-domain Alternatives:
Assume that [[A]] = $\{a\}$ and [[B]] = $\{b\}$. The function, $Alt_{\cup}(\exists$ p([[A or B]])), returns $\{a, b, a \cup b\}$.

Similar as Fox (2007), Alonso-Ovalle (2006) also assumes that the strengthening algorithm cannot be applied to a sentence unless the existential closure operator activates all alternatives of a disjunction. The strengthening algorithm is carried out in two steps. In the first strengthening step (S^{+}), all innocently excludable[13] conjunctive alternatives are negated. In the second strengthening step (S^{++}), the “no privilege” principle is applied. The “no privilege” principle stipulates that either all sub-domain alternatives of a sentence should be true, or all of them should be false. The application of the “no privilege” principle is the most crucial step for deriving free choice inferences.

Let’s see how Alonso-Ovalle’s recursive pragmatic reasoning predicts the inferences of *may/or* sentences such as (14).

(14) Hanna may learn English or Dutch at school.
(14a) S = $\Diamond$ (EN $\vee$ DU)[14] = {$\Diamond$ *learn* (*Hanna*, *English*), $\Diamond$ *learn* (*Hanna*, *Dutch*)}

Under alternative semantics, the logical form of (14) is (14a). When the existential closure operator ($\exists$ p) is applied under the scope of *may*, the two functions which compute the alternatives for (14a) are activated, and they return two sets of alternatives: a set of conjunctive alternatives, i.e., $Alt_{\cap}$(14a), and a set of sub-domain alternatives, i.e., $Alt_{\cup}$(14a).

(14b) $\Diamond$ (($\exists$ p) (EN $\vee$ DU))
(14c) $Alt_{\cap}$(14a) = {$\Diamond$ EN, $\Diamond$ DU, $\Diamond$ (EN $\wedge$ DU)}
$Alt_{\cup}$(14a) = {$\Diamond$ EN, $\Diamond$ DU, $\Diamond$ (EN $\vee$ DU)}[15]

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[12] The review of Hamblin’s rules can be found in Appendix.
[13] Alonso-Ovalle (2006) adopts Fox’s (2007) idea of innocent exclusion. Innocent exclusion is explained in Section 2.2.1.
[14] Notes on abbreviations: EN: English; DU: Dutch.
[15] We temporarily ignore the scalar alternative of *may*, because it does not bring any noticeable change to the results of implicature computation.

The first strengthening step concerns the truth conditions of the conjunctive alternatives. Since $\Diamond$ (EN $\wedge$ DU) is the only innocently excludable alternative, $\Diamond$ (EN $\wedge$ DU) is negated. As a result, the primary implicature in (14d) is derived. It suggests that Hanna is not allowed to learn both English and Dutch at school.

(14d) S^+: $\neg\Diamond$ (EN $\wedge$ DU)

The second strengthening step concerns the truth conditions of the sub-domain alternatives. In this step, the "no privilege" principle is applied. Based on the "no privilege" principle, all sub-domain alternatives, except for the prejacent itself, should be of the same truth value, and in addition, the truth value of them should also be consistent with the speaker's belief on the prejacent. Here, if both $\Diamond$ EN and $\Diamond$ DU are false, the prejacent $\Diamond$ (EN $\vee$ DU) will also be false. So both $\Diamond$ EN and $\Diamond$ DU can only be true. Based on this, the secondary implicature in (14e) can be derived, which is a free choice inference. It suggests that Ann is allowed to learn English, and she is also allowed to learn Dutch.

(14e) S^{++}: $\Diamond$ EN & $\Diamond$ NL
(14f) strengthened meaning: $\Diamond$ (EN $\vee$ DU) & $\neg\Diamond$ (EN $\wedge$ DU) & $\Diamond$ EN & $\Diamond$ DU

Combining the implicatures in (14d) and (14e) with (14a), we obtain the strengthened meaning (14f), which implies that Ann is granted permission to learn English and she is also granted permission to learn Dutch, but she is not granted permission to learn both.

Now Let's see how Alonso-Ovalle's recursive pragmatic reasoning predicts the inferences of *must/or* sentences such as (15).

(15) Jane must pass the English exam or the French exam this month.
a. S = $\Box$ (EN $\vee$ FR)[16] = {$\Box$ *pass* (*Jane*, *the _English_exam*), $\Diamond$ *pass* (*Jane*, *the_French_exam*)}
b. $\Box$ (($\exists$ p) (EN $\vee$ FR))
c. $Alt_{\cap}$(15b) = {$\Box$ EN, $\Box$ FR, $\Box$ (EN $\wedge$ FR)}
$Alt_{\cup}$(15b)= {$\Box$ EN, $\Box$ FR, $\Box$ (EN $\vee$ FR)}
d. S^+: $\neg\Box$ EN & $\neg\Box$ FR & $\neg\Box$(EN $\wedge$ FR)
e. strengthened meaning: $\Box$ (EN $\vee$ FR) & $\neg\Box$ EN & $\neg\Box$ FR & $\neg\Box$(EN $\wedge$ FR)

Different from the *may/or* sentence in (14), all conjunctive alternatives of the *must/or* sentence in (15), which are listed in (15c), can be negated at the first strengthening step without influencing the truth value of the prejacent. The implicatures generated by the first strengthening step, as is shown in (15d), obey the "no privilege" principle: all sub-domain alternatives except for the prejacent iteself, i.e., $\Box$ EN and $\Box$ FR, are false at the same time. Therefore, we derive the strengthened meaning (15e), which implies that Jane is not under the obligation to pass the English exam, that she is not under the obligation to pass the French exam, and that she is also not under the obligation to pass both exams.

[16] Notes on abbreviations: EN: the English exam; FR: the French exam.

2.2.3 Comparisons and Psychological Implications

Two types of *scalar implicature* accounts are discussed in Section 2.2. One type is the grammatical account proposed by Fox (2007), which suggests that the inferences associated with *may/or* sentences and *must/or* sentences are derived by the application of a covert exhaustification operator in syntax. The other type is the pragmatic account proposed by Alonso-Ovalle (2006), which suggests that the inferences associated with *may/or* sentences and *must/or* sentences are the results of Gricean-like reasoning. In this section, I further compare the similarities and differences between Fox's (2007) account and Alonso-Ovalle's (2006) account. More importantly, I discuss the indirect psychological implications of the two accounts.

Fox (2007) and Alonso-Ovalle (2006) make very similar predictions about whether the three types of inferences should be computed for *may/or* sentences and *must/or* sentences. To begin with, they both predict that exhaustivity inferences should be computed for *may/or* sentences and *must/or* sentences by default. The exhaustification operator (*exh*) proposed by Fox and the existential closure operator (∃ p) proposed by Alonso-Ovalle can only operate over a set of alternatives which is semantically closed under disjunction. More specifically, for a *may/or* sentence such as (1c) which is repeated as (16a) or a *must/or* sentences such as (1d) which is repeated as (17a), their alternatives are computed in two steps: first, a closed set of alternatives of the disjunction is computed, i.e., (16b) and (17b); second, all alternatives of the disjunction are further embedded under the deontic modal, i.e., (16c) and (17c).

(16) a. You may clean the dustbins or the windows.
 b. Alt $(d \vee w) = \{d \vee w, d, w, d \wedge w\}$[17]
 c. Alt $(\Diamond (d \vee w)) = \{\Diamond (d \vee w), \Diamond d, \Diamond w, \Diamond (d \wedge w)\}$

(17) a. You must clean the dustbins or the windows.
 b. Alt $(d \vee w) = \{d \vee w, d, w, d \wedge w\}$
 c. Alt $(\Box (d \vee w)) = \{\Box (d \vee w), \Box d, \Box w, \Box (d \wedge w)\}$

According to the maxim of relevance, if a proposition belongs to the formally defined set of alternatives of a disjunction, then it is relevant to the conversational topic and it should be present in the set of worlds of evaluation. On the contrary, if a proposition does not belong to the set of alternatives of a disjunction, then it is irrelevant to the topic and it should be excluded from the set of worlds of evaluation. Based on this, the set of worlds of evaluation of both (16a) and (17a) should not contain the worlds in which you do anything other than cleaning the dustbins and cleaning the windows, such as cleaning the kitchen. If cleaning the kitchen is not an available option in the set of worlds of evaluation, then it can never be a permitted option. Therefore, under Fox and Alonso-Ovalle's accounts, the options other than what is explicitly indicated by the individual disjuncts should not be permitted.

(18) $\Diamond (d \vee w)$
 a. Primary Implicatures: $\neg \Diamond (d \wedge w)$
 b. Secondary Implicatures: $\Diamond d \;\&\; \Diamond w$

[17] Notes on abbreviations: *d*: the dustbins; *w*: the windows.

(19) $\Box\,(d \vee w)$

primary implicatures: $\neg\Box\,(d \wedge w)$ & $\neg\Box\,d$ & $\neg\Box\,w$

Fox and Alonso-Ovalle also similarly predict in which stage free choice inferences and exclusive *or* inferences should be computed. For *may/or* sentences such as the one given in (18), exclusive *or* inferences should be derived at the first exhaustification/pragmatic reasoning step as primary implicatures, while free choice inferences should be derived at the second exhaustification/pragmatic reasoning step as secondary implicatures. For *must/or* sentences such as the one given in (19), free choice inferences should be derived at the first exhaustification/pragmatic reasoning step as primary implicatures. Please especially notice that under Fox and Alonso-Ovalle's accounts, exclusive *or* inferences (e.g. $\neg\Diamond\,(d \wedge w)$) cannot be derived for *must/or* sentences. The primary implicature, $\neg\Box\,(d \wedge w)$, is not equivalent to $\Box\neg(d \wedge w)$. It implies that you are not under the obligation to clean both the dustbins and the windows, but it does not imply that you must not clean both. So it entails a meaning that you are permitted to clean both. Table 2.3 summaries the predictions of *scalar implicature* accounts. Based on Fox and Alonso-Ovalle's accounts, if scalar implicatures are computed, *may/or* sentences should express strong permission, and *must/or* sentences should express permission that is neither weak nor strong.

Table 2.3 Predictions of *Scalar Implicature* Accounts

	***may/or* sentences**	***must/or* sentences**
exhaustivity inferences	semantic constraint/obligatory	semantic constraint/obligatory
free choice inferences	secondary implicature	primary implicature
exclusive *or* inferences	primary implicature	not derivable

Although Fox and Alonso-Ovalle's accounts similarly suggest that free choice inferences and exclusive *or* inferences associated with *may/or* sentences and *must/or* sentences are scalar implicatures in nature, they are crucially different from each other because they propose different types of mechanisms for computing scalar implicatures. As is mentioned at the beginning of this section, Fox's account is a grammatical account, while Alonso-Ovalle's account is a Gricean-like pragmatic account. This difference between the two accounts has some indirect psychological implications on the availability and processing time-courses of the inferences drawn from *may/or* sentences and *must/or* sentences.

Pragmatic accounts and grammatical accounts have different predictions about whether implicature computation involves the cost of cognitive resources. In language processing, the cost of cognitive resources can be reflected by an increase of processing time. Pragmatic accounts (e.g. Grice, 1975) suggest that scalar implicatures are optionally derived and the derivation of them can only take place after logical meanings are derived (i.e., the delayed view[18]). They also suggest that implicature derivation is cognitively costly because when interpreting a sentence, the receiver needs to spend resources to reason about why the speaker utters this specific sentence instead of all other alternatives on the basis of conversational principles (such as the maxim of quantity). According to this, if Alonso-Ovalle successfully

[18] It is also named as the "literal first" view.

predicts the derivation mechanism of inferences drawn from *may/or* sentences and *must/or* sentences, the derivation of free choice inferences and exclusive *or* inferences should be more time-consuming than the derivation of logical meanings. In addition, for *may/or* sentences, the derivation of free choice inferences may even be more time-consuming than the derivation of exclusive *or* inferences because free choice inferences involve one more reasoning step than exclusive *or* inferences.

Different from pragmatic accounts, grammatical accounts (e.g. Chierchia, 2004) argue that implicature derivation is not necessarily a post-sentential process. As soon as a scalar item occurs, the covert exhaustification operator *exh* can be automatically applied to the corresponding semantic structure to compute the scalar implicature. With regard to whether the application of *exh* involves the cost of cognitive resources, there are two opposite possibilities. One possibility is proposed by Levinson (2000). He argues that *exh* is a cognitively costless operator, which should be applied by default (i.e., the default view). Under Levinson's assumption, scalar implicatures should be preferred, while logical meanings should be dispreferred. The cancellation of scalar implicatures for the purpose of making logical meanings salient should be effortful and time-consuming. Based on this, if free choice inferences and exclusive *or* inferences are associated with the application of a cost-free *exh*, we would expect their derivation to take less time than the derivation of logical meanings. Another possibility is proposed by Marty & Chemla (2013), who argue that although the application of *exh* can be cost-free, the decision-making associated with the application of *exh* might consume cognitive resources. Under this possibility, the derivation of free choice inferences and exclusive *or* inferences should still be associated with a processing cost, thus, time-consuming. In Section 3, I further discuss which of the possibilities is a better fit of the experimental data of scalar implicatures.

In brief, *scalar implicature* accounts claim that there is a similarity between exclusive *or* inferences and free choice inferences drawn from disjunction embedded under deontic modals and scalar implicatures. If their assumption is correct, the cognitive behaviors of these two types of inferences, reflected by derivation rates and processing time-courses, should be very similar as those of scalar implicatures.

2.3 *May/or* sentences and *Must/or* Sentences under Semantic Accounts

In this section, I mainly discuss two types of semantic analyses for *may/or* sentences and *must/or* sentences. One type (Zimmermann, 2000; Geurts, 2005) analyzes disjunction as a conjunction of alternatives. The other type (Simons, 2004) analyzes disjunction as an operator which introduces sets of alternatives.

2.3.1 Conjunctive Analysis of Disjunction

The idea that disjunction can be analyzed as a conjunction of propositions was firstly proposed by Zimmermann (2000). He came up with this idea based on the observations such as (20).

(20) a. Context: Mr. White's client, Mr, Brown, visited Mr, White's office, but only Mr. White's colleague, Mr. Tim, was at the office.

b. Mr. Brown: "Do you know where is Mr. White?"

c. Mr. Tim: "**He is in the bathroom or at the tea room.**" (narrow scope *or* sentence)
d. Mr. Tim: "**He is in the bathroom or he is at the tea room.**" (wide scope *or* sentence)
e. Mr. Tim: "**He might be in the bathroom and he might be at the tea room.**"

Zimmermann regards narrow scope *or* sentences such as the one in (20c) as semantically equivalent to their corresponding wide scope *or* counterparts[19] such as the one in (20d). (20d) has a very similar meaning as the sentence in (20e), which is a conjunction of two epistemic possibilities. Based on this, Zimmermann analyzes narrow scope *or* sentences such as (20c) as conjunctive lists of epistemic possibilities. To write it formally:

(21) $is\ (he, in\_the\_bathroom \lor at\_the\_tea\_room)$
$\Leftrightarrow is\ (he, in\_the\_bathroom) \lor is\ (he, at\_the\_tea\_room)$
$\Leftrightarrow \blacklozenge\ is\ (he, in\_the\_bathroom) \land \blacklozenge\ is\ (he, at\_the\_tea\_room)$
Note: ♦ symbolizes the epistemic possibility modal.

Based on (21), the semantics of the *may/or* sentence given in (22) should be equivalent to (22b) and (22c).

(22) You may have the cake or the tart.
a. $\lozenge\ have\ (you, the\_cake \lor the\_tart)$
b. $\lozenge\ have\ (you, the\_cake) \land \lozenge\ have\ (you, the\_tart)$
c. $\blacklozenge \lozenge\ have\ (you, the\_cake) \land \blacklozenge \lozenge\ have\ (you, the\_tart)$[20]
d. After applying the authority principle, $\lozenge\ have\ (you, the\_cake) \land \lozenge\ have\ (you, the\_tart)$
Notes: ◊ symbolizes the deontic possibility modal; ♦ symbolizes the epistemic possibility modal.
(see Zimmermann, 2000, p. 285)

(22c) conveys a meaning that it is possible that you are permitted to have the cake and it is also possible that you are permitted to have the tart. This meaning expresses the speaker's uncertainty and lack of knowledge/opinion about what is definitely permitted. It is very different from free choice inferences which express the speaker's certainty about what is permitted. Now the problem is how to reduce the doubly modalized interpretation in (22c) to the interpretation containing a single modal in (22d). Zimmermann proposes a solution known as "the authority principle" (p. 286). The authority principle stipulates that if the speaker of an utterance is an authority under a given context and if he/she has all the knowledge associated with the utterance, then what he/she thinks is permitted is equivalent to what is actually permitted. By applying the authority principle, ♦ ◊ can be reduced to ◊. Although Zimmermann's analysis successfully predicts the free choice inferences of *may/or* sentences, it fails to explain the free choice inferences of *must/or* sentences.

(23) You must eat the noodles or the rice.

[19] Narrow *or* sentences are the sentences in which disjunction is embedded under deontic modals. Wide *or* sentences are the sentences in which disjunction takes scope over deontic modals.
[20] Please notice that here the epistemic possibility modal ♦ should take the scope over the deontic possibility modal ◊ because (22a) is equivalent to (22b). Disjunction takes the scope over the deontic modal in (22b). In addition, based on previous arguments, disjunction should conjunctively coordinates a list of propositions which express epistemic possibilities.

a. □ *eat* (*you*, *the_noodles* ∨ *the_rice*)
b. □ *eat* (*you*, *the_noodles*) ∨ □ *eat* (*you*, *the_rice*)
c. ♦ □ *eat* (*you*, *the_noodles*) ∧ ♦ □ *eat* (*you*, *the_rice*)
d. After applying the authority principle, □ *eat* (*you*, *the_noodles*) ∧ □ *eat* (*you*, *the_rice*)
⇔ □ *eat* (*you*, *the_noodles* ∧ *the_rice*)
Notes: □ symbolizes the deontic necessity modal; ♦ symbolizes the epistemic possibility modal.

Under Zimmermann's account, (23a) is semantically equivalent to (23c) which indicates that it is possible that you are under the obligation to eat the noodles and it is also possible that you are under the obligation to eat the rice. If we apply the authority principle to (23c), we will obtain (23d). (23d) is a false interpretation of (23) because it indicates that you must eat the noodles and the rice at the same time. (23d) is very different from the free choice inference we want to derive for (23), which should be that you are allowed to eat the noodles and you are allowed to eat the rice.

The fact that Zimmermann's analysis cannot be applied to *must/or* sentences suggests that it might be problematic to analyze disjunction as an operator which conjoins propositions denoting epistemic possibilities. Geurts (2005) points out that the semantics of disjunction plays no role in settling the modal status of a sentence. He proposes that disjunction in *may/or* sentences and *must/or* sentences should be analyzed as a conjunction of modal propositions which contain covert presuppositions. Geurt's presuppositional analysis of modal propositions is developed on the basis of observations such as (24):

(24) a. You may play the video game.
b. If you finish the homework, you may play the video game.

(24a) merely indicates that a permission is granted for playing the video game. To some extent, the information related to this permission is incomplete because we do not know under what circumstance the permission is licensed. It would only be trivially meaningful if we interpret it as that playing the video game is allowed under all circumstances. By contrast, (24b) sounds much more reasonable. When granting permission, people always specify the circumstances related to it. For example, in (24b), the permission for playing the video game is only valid under a specific circumstance, i.e., the circumstance that the homework has been done. Based on this, Geurts proposes that every modal proposition contains a covert *if*-clause as its presupposition. Following Kratzer's (1986) theory of conditionals, Geurts claims that the covert *if*-clauses of a modal proposition can restrict the domain of the overt modal occurred in this modal proposition. In order to make it more clear, let's consider (24b) once again, which is repeated as (25).

(25) If you finish the homework, you may play the video game.
a. [[*finish* (*you*, *the_homework*)]] ◊ [[*play* (*you*, *the_video_game*)]]
b. $ACC_{d,\ w*}$ = [[*finish* (*you*, *the_homework*)]]
c. [[*finish* (*you*, *the_homework*)]] ∩ [[*play* (*you*, *the_video_game*)]] ≠ Ø
Note: ◊ symbolizes the deontic possibility modal.

(25a) is the logical form of (25). Based on Geurts, the presupposition, *you finish the homework*, can restrict the domain of the deontical posibility modal, *may*, in the proposition, *you may play the video game*. So as is shown in (25b), the domain of *may* is a set of worlds in which you finish the homework. (25c) is the truth condition of (25a). (25a) is true if and only if there exists at least a world in which you finish the homework and you play the video game. As a result, (25) conveys a meaning that one of the things you are allowed to do after you finish the homework is to play the video game.

After figuring out how Geurts analyzes modal propositions, let's further see how he analyzes propositions with disjunction embedded under modals. Similar as Zimmermann, Geurts assumes that narrow scope *or* sentences are semantically equivalent to wide scope *or* sentences. Now suppose that we have a sentence in the form of "p_1 *or* p_2 *or...or* p_n". p_1, p_2...and p_n are modal propositions which contain the same modal. Based on Geurts, each p_x ($1 \leqq x \leqq n$) contains a covert *if*-clause as its presupposition. If we assume that the presupposition of p_x is symbolized as A_x, then p_x should be interpreted as "if A_x, then p_x". If we represent the overt modal in p_x as M and the descriptive content in p_x as B_x, then "p_1 *or* p_2 *or...or* p_n" has an interpretation that $A_1\ _M\ B_1 \wedge A_2\ _M\ B_2 \wedge \ldots \wedge A_n\ _M\ B_n$. This is the free choice interpretation that is always preferred. For $A_1\ _M\ B_1 \wedge A_2\ _M\ B_2 \wedge \ldots \wedge A_n\ _M\ B_n$, by default, we assume that $ACC_{w^*} = A_1 = A_2 = \ldots = A_n$ (ACC_{w^*} is a set of accessible worlds). Only when this assumption is unfeasible, we subsequently assume that $A_1 \subseteq ACC_{w^*}$ & $A_2 \subseteq ACC_{w^*}$ &...& $A_n \subseteq ACC_{w^*}$. Furthermore, Geurts proposes two extraneous constraints for $A_1\ _M\ B_1 \wedge A_2\ _M\ B_2 \wedge \ldots \wedge A_n\ _M\ B_n$:

(26) Exhaustivity Constraint:

$$ACC_{w^*} \subseteq (A_1 \cap B_1) \cup (A_2 \cap B_2) \cup \ldots \cup (A_n \cap B_n)$$

(See Geurts, 2005, p. 395)

This constraint guarantees that the set of accessible worlds contains nothing more than what is explicitly indicated by the individual disjuncts. Following Zimmermann, Geurts claims that the exhaustivity constraint is a semantic constraint, which should be applied by default[21].

(27) Exclusive *or* Constraint:

$$(A_1 \cap B_1) \cap (A_2 \cap B_2) \cap \ldots \cap (A_n \cap B_n) = \emptyset$$

(See Geurts, 2005, p. 395)

If the exclusive *or* constraint is applied, there should be no intersection between the sets of worlds denoted by each of the disjuncts, so *or* is interpreted exclusively. Geurts claims that the exclusive *or* constraint should be a pragmatic constraint, and the exclusive *or* inferences should be some sort of conversational implicatures. Please notice that if the exclusive *or* constraint proposed here is a Gricean-like pragmatic constraint, the application of it should be optional.

(28) and (29) below illustrate how *may/or* sentences and *must/or* sentences are interpreted under Geurts's account.

[21] Zimmermann (2000) and Geurts (2005) similarly claim that except for the circumstance in which disjunction is marked by a high phrase-final tone, in all other circumstances, disjunction should be closed in semantics.

(28) You may feed the dog or the cat.

= You may feed the dog or you may feed the cat.

a. B_1 = [*feed* (*you*, *the_dog*)]], A_1 = the presupposition of B_1

B_2 = [[*feed* (*you*, *the_cat*)]], A_2 = the presupposition of B_2

b. $A_1 \Diamond B_1 \wedge A_2 \Diamond B_2$

$(A_1 \cap B_1 \neq \emptyset, A_2 \cap B_2 \neq \emptyset, A_1 \neq \emptyset, A_2 \neq \emptyset)$

c. by default: $ACC_{d,w^*} = A_1 = A_2$

d. exhaustivity constraint: $ACC_{d,w^*} \subseteq (A_1 \cap B_1) \cup (A_2 \cap B_2) \Leftrightarrow ACC_{d,w^*} \subseteq (B_1 \cup B_2)$[22]

e. exclusive *or* constraint: $(A_1 \cap B_1) \cap (A_2 \cap B_2) = \emptyset \Leftrightarrow B_1 \cap B_2 = \emptyset$[23]

(See Geurts, 2005, p. 396)

If we assume that (28) is equivalent to its wide scope *or* counterpart (i.e., *you may feed the dog or you may feed the cat*), then A_1 and A_2 are the domains of the deontic possibility modals in each of the individual disjuncts. By combining (28b) with (28c), we will get $ACC_{d,w^*} \cap B_1 \neq \emptyset$ and $ACC_{d,w^*} \cap B_2 \neq \emptyset$. This gives rise to a free choice inference which indicates that in the set of worlds which are deontically accessible from the the set of worlds of evaluation, there should exist at least one world in which you feed the dog and there should also exist at least one world in which you feed the cat. To make it short, it means that you are allowed to feed the dog and you are also allowed to feed the cat. If we combine (28c) with (28d), we will get $ACC_{d,w^*} \subseteq (B_1 \cup B_2)$, which suggests that the set of deontiaclly accessible worlds should only include the type of worlds in which you feed the dog and the type of worlds in which you feed the cat, and it should not include any world other than these two types of worlds. So if the exhaustivity constraint is applied, we will derive the inference that you are not allowed to do anything other than feeding the dog and feeding the cat. Furthermore, if we combine (22b) and (22c) with (22e), we will get that $B_1 \cap B_2 = \emptyset$, which indicates that there should exist no world in which you feed the dog and the cat at the same time. So if the exclusive *or* constraint is applied, we will derive the inference that you are not allowed to feed both pets.

(29) You must feed the dog or the cat.

= You must feed the dog or you must feed the cat.

a. B_1 = [*feed* (*you*, *the_dog*)]], A_1 = the presupposition of B_1

B_2 = [[*feed* (*you*, *the_cat*)]], A_2 = the presupposition of B_2

b. $A_1 \Box B_1 \wedge A_2 \Box B_2$

$(A_1 \subseteq B_1, A_2 \subseteq B_2, A_1 \neq \emptyset, A_2 \neq \emptyset)$

c. the assumption that $ACC_{d,w^*} = A_1 = A_2$ fails, so $A_1 \subseteq ACC_{d,w^*}$ & $A_2 \subseteq ACC_{d,w^*}$[24].

[22] According to (28c), $ACC_{d,w^*}=A_1=A_2$. If we replace A_1 and A_2 in (28d) with ACC_{d,w^*}, we will get $ACC_{d,w^*} \subseteq (ACC_{d,w^*} \cap B_1) \cup (ACC_{d,w^*} \cap B_2)$. According to the distributive law in set theory, $(ACC_{d,w^*} \cap B_1) \cup (ACC_{d,w^*} \cap B_2) = ACC_{d,w^*} \cap (B_1 \cup B_2)$. Thus, we further have $ACC_{d,w^*} \subseteq ACC_{d,w^*} \cap (B_1 \cup B_2)$. If the set ACC_{d,w^*} is a subset of the intersection of itself and the union of the set B_1 and the set B_2, then ACC_{d,w^*} must be a subset of the union of B_1 and B_2. Therefore, (28d) can eventually be simplified to $ACC_{d,w^*} \subseteq (B_1 \cup B_2)$.

[23] Since $ACC_{d,w^*}=A_1=A_2$, if we replace A_1 and A_2 in (28e) with ACC_{d,w^*}, then we will get $(ACC_{d,w^*} \cap B_1) \cap (ACC_{d,w^*} \cap B_2) = \emptyset$. According to the commutative law in set theory, $(ACC_{d,w^*} \cap B_1) \cap (ACC_{d,w^*} \cap B_2) = ACC_{d,w^*} \cap B_1 \cap B_2$. So we further have $ACC_{d,w^*} \cap B_1 \cap B_2 = \emptyset$. According to (28b) and (28c), $ACC_{d,w^*} = A_1 = A_2 \neq \emptyset$. If $ACC_{d,w^*} \neq \emptyset$ and $ACC_{d,w^*} \cap B_1 \cap B_2 = \emptyset$, then we will get $B_1 \cap B_2 = \emptyset$.

[24] If we assume that $ACC_{d,w^*} = A_1 = A_2$, we will get the interpretation that in all worlds which are deontically accessible, you feed the dog, and that in all worlds which are deontically accessible, you feed the cat. To simplify, it means that you must

d. exhaustivity constraint: $ACC_{d,w^*} \subseteq (A_1 \cap B_1) \cup (A_2 \cap B_2) \Leftrightarrow ACC_{d,w^*} \subseteq (B_1 \cup B_2)$[25]

e. exclusive *or* constraint: $(A_1 \cap B_1) \cap (A_2 \cap B_2) = \emptyset \Leftrightarrow A_1 \cap A_2 = \emptyset$[26]

(See Geurts, 2005, p. 397)

If we assume that (29) is equivalent to its wide scope *or* counterpart (i.e., *you must feed the dog or you must feed the cat*), then A_1 and A_2 are the domains of the deontic necessity modals in each of the disjuncts. The combination of (29b) with (29c) can give rise to a free choice inference, which suggests that there are some deontically accessible worlds, in which you feed the dog, and that there are also some deontically accessible worlds, in which you feed the cat[27]. By applying the exhaustivity constraint, we will get (29d). (29d) suggests that in the set of deontically accessible worlds, only the dog and the cat are available options. By the applying the exclusive *or* constraint, we will get (29e), which suggests that there exists no intersection between the domain of the deontic necessity modal in the proposition that *you must feed the dog* and the domain of the deontic necessity modal in the proposition that *you must feed the cat*. Alternatively, it suggests that among all deontically accessible worlds in which you feed the dog, there exists none of them in which you also feed the cat. Similarly, among all deontically accessible worlds in which you feed the cat, there exists none of them in which you also feed the dog. So (29e) indicates that there exists no deontically accessible world in which you feed both the dog and the cat.

2.3.2 Disjunction as Sets of Alternatives

Simons (2004) proposes that when deontic modals operate over disjunction, disjunction can introduce sets of alternative propositions. To figure out how the deontic modal in a narrow *or* sentence can operate over sets of propositions, let's consider (30) and (31).

(30) Kate may bring a magazine or a novel.

a. ◊ *bring* (*Kate*, *a_magazine* ∨ *a_novel*)

b. ◊ (*bring* (*Kate*, *a_magazine*) ∨ *bring* (*Kate*, *a_novel*)) (independence composition)

c. ◊ {{[[*bring* (*Kate*, *a_magazine*)]]}, {[[*bring* (*Kate*, *a_novel*)]]}} (alternative semantics)

(31) Kate must bring a magazine or a novel.

a. □ *bring* (*Kate*, *a_magazine* ∨ *a_novel*)

b. □ (*bring* (*Kate*, *a_magazine*) ∨ *bring* (*Kate*, *a_novel*)) (independence composition)

c. □ {{[[*bring* (*Kate*, *a_magazine*)]]}, {[[*bring* (*Kate*, *a_novel*)]]}} (alternative semantics)

According to Simons, narrow scope *or* sentences such as the *may/or* sentence in (30) and the

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feed the dog and cat. This interpretation is not in consistency with the fact that you are only under the obligation to feed at least one of the pets indicated by the disjuncts, but you are not under the obligation to feed both of them. Since the default assumption that $ACC_{d,w^*} = A_1 = A_2$ is not feasible, we can only assume that $A_1 \subseteq ACC_{d,w^*}$ & $A_2 \subseteq ACC_{d,w^*}$.

[25] If $A_1 \subseteq B_1$ & $A_2 \subseteq B_2$ (based on (29b)), then $A_1 \cap B_1 = A_1$ and $A_2 \cap B_2 = A_2$. As a result, $(A_1 \cap B_1) \cup (A_2 \cap B_2) = A_1 \cup A_2$. So we can simplify (29d) as that $ACC_{d,w^*} \subseteq (A_1 \cup A_2)$. Since $A_1 \subseteq B_1$ & $A_2 \subseteq B_2$, we will get $(A_1 \cup A_2) \subseteq (B_1 \cup B_2)$. Eventually, we deduce that $ACC_{d,w^*} \subseteq (B_1 \cup B_2)$.

[26] Since $A_1 \cap B_1 = A_1$ and $A_2 \cap B_2 = A_2$ (see Footnote 25), $(A_1 \cap B_1) \cap (A_2 \cap B_2) = \emptyset$ can be simplified to $A_1 \cap A_2 = \emptyset$.

[27] If $A_1 \subseteq ACC_{d,w^*}$ and $A_1 \subseteq B_1$, then the relation between ACC_{d,w^*} and B_1 has three possibilities. First, B_1 is a subset of ACC_{d,w^*}. Second, B_1 equals to ACC_{d,w^*}. Third, B_1 is a superset of ACC_{d,w^*}. All those three possibilities imply that there are some worlds which belong to both ACC_{d,w^*} and B_1. The same reasoning can also be applied to the relation between ACC_{d,w^*} and B_2.

must/or sentence in (31) with logical forms as (30a) and (31a) can become (30b) and (31b) by going through a process known as independence composition. Independence composition is very simimlar to Hamblin's rules (see Appendix). She further suggests that independence composition is preferably halted at deontic modals due to some unspecified reason[28]. If independent composition is halted at a deontic modal as is illustrated in (30b) and (31b), the modal then operates over a disjunction which contains two propositional individual disjuncts. In this situation, the alternative semantics of disjunction can be activated. As is shown above, the alternative semantics of (30b) is (30c), and the alternative semantic of (31b) is (31c). In both cases, the disjunction, *bring* (*Kate*, *a_magazine*) ∨ *bring* (*Kate*, *a_novel*), is analyzed as a set containing two members which are also sets, i.e., {{[[*bring* (*Kate*, *a_magazine*)]]}, {[[*bring* (*Kate*, *a_novel*)]]}}.

Simons keeps the standard semantics for deontic modals, under her account, the truth condition of (30c) is (32a), while the truth condition of (31c) is (32b).

(32) a. ◊ {{[[*bring* (*Kate*, *a_magazine*)]]}, {[[*bring* (*Kate*, *a_novel*)]]}} is true at w^* iff $\exists S \subseteq ACC_{d,w^*}$ s.t. S is divided up into[29] {[[*bring* (*Kate*, *a_magazine*)]]} and {[[*bring* (*Kate*, *a_novel*)]]}.

b. □ {{[[*bring* (*Kate*, *a_magazine*)]]}, {[[*bring* (*Kate*, *a_novel*)]]}} is true at w^* iff $\exists S = ACC_{d,w^*}$ s.t. S is divided up into {[[*bring* (*Kate*, *a_magazine*)]]} and {[[*bring* (*Kate*, *a_novel*)]]}.

Note: S is the abbreviation for *set*.

(See Simons, 2004, p. 5-6)

(32a) says that the sentence, *Kate may bring a magazine or a novel*, is true if and only if there exists at least one subset in the set of deontically accessible worlds, which contains a type of worlds in which Kate brings a magazine and a type of worlds in which Kate brings a novel. According to this, the sentence entails a free choice inference that there is a permission for Kate to bring a magazine and there also is a permission for Kate to bring a novel. However, we need to notice that the set of deontically accessible worlds may also contain other types of worlds. The sentence, therefore, is not exhaustified. (32b) says that the sentence, *Kate must bring a magazine or a novel*, is true if and only if the set of deontically accessible worlds itself can only be categorized into a type of worlds in which Kate brings a magazine and a type of worlds in which Kate brings a novel. Based on this, the sentence entails a free choice inference that there is a permission for Kate to bring a magazine and there also is a permission for Kate to bring a novel. In addition, it also entails an exhaustivity inference that there exists no permission for Kate to do anything else because the entire set of the deontically accessible worlds only contains two options: to bring a magazine and to bring a novel.

Till this point, we have seen how free choice inferences can be derived as parts of truth conditions of *may/or* sentences and *must/or* sentences, and why exhaustivity inferences are derived for *must/or* sentences but not for *may/or* sentences. Now the only thing which still needs some more discussion is to what extent we should allow for the overlapping between individual disjuncts. According to Simons, there are three types of pragmatic constraints

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[28] Simons suggests that the reason might be that the VP below MP is the first possible opportunity for halting the independent composition.

[29] I simplify Simons's (2004) idea of supercover (p.5) by explicitly mentioning the meaning of supercover. Supercover divides up the set of worlds of evaluation into different categories of worlds. More specifically, the supercover of *A or B* is a set which contains a set of [[A]] worlds and a set of [[B]] worlds.

concerning the overlapping between disjuncts: the non-containment constraint, the no-total-overlap constraint and the alternativeness constraint. To state it simply, the non-containment constraint and the no-total-overlap constraint are two constraints that are dependent on each other. The combined effect of them ensures that the set of worlds denoted by an individual disjunct is not a subset of the set of worlds denoted by any other disjunct in the same disjunction. The alternativeness constraint is an independent constraint, which ensures that there exists no overlapping between the set of worlds denoted by each of the individual disjuncts in a disjunction. If a sentence satisfies the alternativeness constraint, it is well-formed, thus, highly acceptable. If a sentence violates the alternativeness constraint but obeys the non-containment constraint and the no-total-overlap constraint, it is weakly anomalous, but still acceptable. If a sentence violates the non-total-overlap constraint and the non-containment constraint, it is strongly anomalous, thus very unacceptable. By applying the alternativeness constraint, exclusive *or* inferences can be derived[30].

2.3.3 Comparisons and Psychological Implications

In Section 2.3, I have discussed two types of accounts which adopt alternative semantics to analyze *may/or* sentences and *must/or* sentences. One type (i.e., Zimmermann, 2000; Geurts, 2005) is the conjunctive analysis of disjunction, while the other type (e.g., Simons, 2004) suggests that disjunction can denote sets of alternative propositions under deontic modals. These accounts have some similarities and differences in predicting the availability of the three types of inferences associated with *may/or* sentences and *must/or* sentences, and they also have some indirect psychological implications on the cognitive behaviors of the inferences drawn from *may/or* sentences and *must/or* sentences.

For *may/or* sentences such as *you may clean the dustbins and the windows* and *must/or* sentences such as *you must clean the dustbins and the windows*, the semantic accounts reviewed in this section similarly suggest that under the alternative semantics, the computation of truth conditions can give rise to free choice inferences (i.e., *you are allowed to clean the dustbins and you are allowed to clean the windows*). Therefore, free choice inferences can be regarded as preferred logical meanings of *may/or* sentences and *must/or* sentences. If free choice inferences are, in effect, logical meanings, they should be computed alongside with the computation of logical forms in syntax, and their derivation should be immediate and effortless. Furthermore, the semantic accounts also similarly predict that exclusive *or* inferences (i.e., *you are not allowed to clean both the dustbins and the windows*) should be derived as the results of the application of a Gricean-like pragmatic constraint. If this prediction is correct, exclusive *or* inferences should behave very similarly as conversational implicatures, or more specifically, scalar implicatures. According to pragmatic accounts (e.g. Grice, 1795) which suggest that the computation of scalar implicatures is effortful and time-consuming, the processing time of exclusive *or* inferences should be much longer than that of logical meanings. With regard to exhaustivity inferences (i.e., *you are not allowed to do anything other than cleaning the dustbins and cleaning the windows*), the semantic accounts uniformly predict that they should be obligatorily computed as parts of truth conditions of *must/or* sentences. However, they disagree with each other concerning whether exhaustivity inferences should also be computed for *may/or* sentences. Zimmermann

[30] The detailed explanation of the three constraints can be found in Simons, 2004, p. 29-31.

(2000) and Geurts (2005) propose that the exhaustivity constraint should be apply to the semantics of *may/or* sentences by default because disjunction introduces a closed set of alternatives. By contrast, based on Simons (2004), the exhaustivity constraint should be excluded from the computation of truth conditions of *may/or* sentences due to the semantics of deontic possibility modals. Table 2.4 briefly summarizes what I have discussed in this section. Under Zimmermann's (2000) and Geurts's (2005) accounts (i.e., conjunctive analysis), both *may/or* sentences and *must/or* sentences can be used to grant strong permission if the exclusive *or* constraint is applied. Under Simons's (2004) account (i.e., sets analysis[31]), *must/or* sentences should grant strong permission if the exclusive *or* constraint is applied, while *may/or* sentences should grant weak permission if the exclusive *or* constraint is not applied.

Table 2.4 Predictions of Semantic Accounts

	***may/or* sentences**	***must/or* sentences**
exhaustivity inferences	semantic constraint/ under conjunctive analysis: obligatory; under sets analysis: absent	semantic constraint/obligatory
free choice inferences	logical meaning	logical meaning
exclusive *or* inferences	pragmatic constraint	pragmatic constraint

2.4 Summary

In Section 2, I have discussed how *scalar implicature* accounts (Section 2.2) and semantic accounts (Section 2.3) analyze *may/or* sentences and *must/or* sentences.

The accounts I have reviewed are different from each other in following aspects. First, the most crucial difference between *scalar implicature* accounts and semantic accounts lies in their predictions about the derivation mechanism of free choice inferences. *Scalar implicature* accounts predict that free choice inferences share the same derivation mechanism with scalar implicatures. If it is the case, in cognition, they should behave similarly as scalar implicatures. Semantic accounts predict that free choice inferences are the results of the computation of truth conditions. If it is the case, they should have similar cognitive behaviors as logical meanings. Second, although all accounts I have reviewed uniformly claim that exhaustivity inferences are derived semantically and exclusive *or* inferences are (similar as) scalar implicatures, some of them are different from others in predicting the availability of these two types of inferences. For example, sets analysis (i.e., Simons, 2004) predicts that exhaustivity inferences should only be derived for *may/or* sentences but not for *must/or* sentences, while the rest of the accounts predict that exhaustivity inferences should be derived for both *may/or* sentences and *must/or* sentences. *Scalar implicature* accounts (i.e., Fox, 2007; Alonso-Ovalle, 2006) predict that exclusive *or* inferences should only be derived for *may/or* sentences but not *must/or* sentences, while semantic accounts predict that exclusive *or* inferences can be derived for both types of sentences.

The brief summary given above suggests that if we want to have a clear understanding about how *may/or* sentences and *must/or* sentences are processed in cognition, we need to figure out two things: the availability and the derivation mechanism of the three types of

[31] *Sets analysis* is a short name for the account which analyzes disjunction as sets of propositions (i.e., Simons, 2004).

inferences associated with *may/or* sentences and *must/or* sentences. To make it clearer, we need to figure out how likely these inferences can be derived, and whether they are scalar implicatures or parts of logical meanings. Very importantly, if we want to know whether an inference behaves like scalar implicatures or logical meanings, we should first understand the cognitive behaviors of scalar implicatures and logical meanings. The cognitive behaviors of logical meanings are relatively less-disputed in the psychological field. Most commonly, the computation of logical meanings is assumed to takes place immediately without being accompanied by the cost of cognitive resources. Compared with this, the assumptions about the cognitive behaviors of scalar implicatures are more diversified. As I have mentioned in Section 2.2.3, theoretically, the derivation of scalar implicatures could be optional and cognitively costly, but it could also be a default choice which is cost-free. In order to have a clearer idea about the cognitive behaviors of scalar implicatures, in next section (i.e., Section 3.1), I discuss the experimental data of scalar implicatures in previous studies.

3 Previous Experimental Studies

Several recent experimental studies examined to what extent free choice inferences can be drawn from disjunction embedded under deontic possibility modals and whether there is a similarity between free choice inferences and scalar implicatures. The reason why they compare free choice inferences with scalar implicatures is that based on Alonso-Ovalle (2006) and Fox (2007), free choice inferences can be derived by the same mechanism as that of scalar implicatures. If the same mechanism is involved, we would expect a similarity in cognitive behaviors between free choice inferences and scalar implicatures. This section, thus, includes a survey of experimental studies on the processing of scalar implicatures (Section 3.1) as well as the interpretation of disjunction embedded under deontic possibility modals (Section 3.2).

3.1 Experimental Studies on Scalar Implicatures

In this section, I focus on discussing the scalar implicatures associated with two classical scalar items: *some* and *or*. In addition, I only discuss the studies which adopted situation-sentence binary judgment tasks as the experimental paradigms. The reason why I do so is that in psychological experiments, the difference in the type of tasks involved can cause the difference in experimental results (see Geurts & Pouscoulous, 2009), so experimental data obtained in different types of tasks are not very comparable with each other. Since at a later point, I want to know whether the processing patterns of the inferences observed under my paradigm (i.e., a picture-sentence binary judgment task) have any similarities with the processing pattern of scalar implicatures, here I decide to limit the discussion to the experimental data of scalar implicatures obtained in the tasks similar as the one I adopted in my experiment, so that the processing patterns could be comparable with each other. Based on this, studies which involve visual world paradigms (e.g. Grodner, et al., 2010), Likert scales (e.g. Katsos & Bishop, 2011), etc., are not discussed here.

The derivation of scalar implicatures is associated with the competition between an uttered sentence and its stronger alternatives. The discussions of the processing of scalar implicatures center on how frequently scalar implicatures can be derived and whether their derivation is cognitively costly. One of the most frequently cited experimental studies on the processing of scalar implicatures was done by Bott & Noveck (2004). In their experiments, they asked participants to judge whether a sentence is true or false based on the world knowledge. The target sentences, containing the scalar item *some*, are ambiguous between a logical meaning and a strengthened meaning. For example, one of the target sentences they used is *some elephants are mammals*. If participants interpreted the sentence logically, they would judge the sentence as true because the logical meaning of *some* indicates *some perhaps all*. By contrast, if participants derived scalar implicatures, they would interpret *some* as *some but not all*. Since the world knowledge suggests that all elephants are mammals, the sentence should be judged as false when scalar implicatures were derived. The results of the experiments indicate two things: first, the scalar implicatures associated with *some* were not derived by default. Without training, the derivation rate of the scalar implicatures was around 60%. Second, it took participants a significantly longer time to make responses associated with scalar implicatures than making responses associated with logical interpretations. Based on the results, Bott & Noveck claim that scalar implicatures should be optionally derived. The delayed derivation of scalar implicatures in comparison to logical interpretations indicates a deeper processing of the sentences and a cost of cognitive resources. Bott & Noveck's delayed view of scalar implicatures runs against the default view of scalar implicatures (Levinson, 2000), which claims that scalar implicatures should be derived immediately as the default interpretations, while logical interpretations should be derived after the cancellation of scalar implicatures.

The delayed view of scalar implicatures is also supported by the results from other studies. Chevallier et al (2008) examined the processing of the sentences containing the scalar item *or*. In their experiments, participants were first presented with a chain of letters such as *TABLE*, then they were asked to judge whether a sentence, such as *there is an A or a B*, is correct or incorrect. If participants interpreted *or* logically, they would judge the sentence as true because the semantics of *or* suggests that as long as there exists at least one of A and B, the sentence is true. However, if participants computed the scalar implicature which suggests that there should exist only one of A and B, they would judge the sentence as false. The results of this study indicate that when the letters were presented at a normal speed, the derivation rate of the scalar implicatures associated with *or* was around 25%, and the responses related to scalar implicatures were delayed compared with those related to logical interpretations.

To sum up, based on Bott & Noveck (2004) and Chevallier et al (2008), in situation-sentence binary judgment tasks, the derivation of scalar implicatures should be delayed and optional.

3.2 Experimental Studies on Disjunction under Deontic Possibility Modals

All previous studies only examined free choice inferences drawn from disjunction embedded under deontic possibility modals, but none of them examined exhaustivity inferences and exclusive *or* inferences. In addition, none of them examined any type of inferences drawn from disjunction embedded under deontic necessity modals.

van Tiel (2012) conducted an experiment in Dutch, which examined to what extent free choice inferences can be drawn from disjunction embedded under various types of modals (e.g. deontic modals, epistemic modals and dynamic modals). The experiment was carried out in the form of questionnaire survey. The questionnaire always showed a sentence followed by a conclusion. For example, one of the target sentences in the questionnaire was that *Jan was allowed to take an apple or a banana*. It was followed by a conclusion that *Jan was allowed to take an apple*. Participants were required to indicate the strength of the conclusion in a 0-100% scale given the corresponding sentence. The results of the experiment indicate that free choice inferences drawn from disjunction embedded under deontic possibility modals were the strongest (the median of the inference strength was as high as 95%). Based on this, van Tiel concludes that free choice inferences related to permission granting are very robust.

Chemla (2009) compared the strength of free choice inferences drawn from disjunction embedded under deontic possibility modals with the strength of scalar implicatures drawn from the <*most*, *all*> scale in both embedded and unembedded environments. The experiment was done in French and in the form of questionnaire survey. For each sentence in the questionnaire, a context story was given. Each sentence was followed by an inference. For example, one of the target sentences in the questionnaire is *Marie is allowed to take Algebra* *or Literature*. For this sentence, a context story conveyed the information that *no one is allowed to take both Algebra and Literature* was provided[32]. Participants were asked to rate to what extent the sentence implies that *Marie can choose which course she will take*. The results of the experiment show that there was no difference in strength between unembedded and embedded free choice inferences (93.33 % vs 90%), but there was a significant difference in strength between unembedded and embedded scalar implicatures. Unembedded scalar implicatures were of a greater implicature strength than embedded scalar impliclatures (83.33% vs 40%). In addition, although embedded free choice inferences were significantly stronger than embedded scalar implicatures, unembedded free choice inferences were roughly as strong as unembedded scalar implicatures. Chelma proposes two possible explanations for the differences between free choice inferences and scalar implicatures. First, free choice inferences and scalar implicatures might involve different processing mechanisms. Second, there might be an independent mechanism for deriving embedded free choice inferences, which is not available for embedded scalar implicatures. Based on Chelma's results, we can merely conclude that there seems to be a difference between free choice inferences and scalar implicatures, but we are unable to make any claim about the processing source of free choice inferences because no reaction time data was recorded. In addition, the paradigm adopted by Chemla may also be problematic. According to Geurts & Pouscoulous (2009), participants have a higher derivation rate and acceptance rate towards inferences that are explicitly given. Thus, the paradigm adopted by Chemla might have biased participants towards deriving both free choice inferences and scalar implicatures. The strengths of both types of inferences might be largely exaggerated.

Chemla & Bott (2014) carried out a series of online experiments in English, which investigated the processing pattern of free choice inferences drawn from disjunction embedded under deontic possibility modals, and they further compared the processing pattern of free choice inferences with that of scalar implicatures. A sentence verification task was adopted as the paradigm in all experiments of this study. In each task, a cover story was firstly presented. The cover story conveyed the information that engineers and zoologists are allowed to freely choose one and only one object to save based on their corresponding profession. Then a target sentence such as *Beverly-the-engineer is allowed to save a hammer or a lion* was presented. Participants were required to judge whether the sentence is correct or incorrect based on the world knowledge and the cover story. The sentence should be judged as correct if it was interpreted logically, i.e., Beverly-the-engineer is allowed to save at least one object among a hammer and a lion. However, if the free choice inference of the sentence, which implies that Beverly-the-engineer is allowed to save a hammer and she is also allowed to save a lion, was derived, the sentence should be judged as incorrect. There are four important findings in this study. First, without training, a majority of participants derived free choice inferences (the derivation rate was 66%). Second, it took participants significantly longer time to make responses associated with logical interpretations than making responses associated with free choice inferences. However, the reversed pattern was observed in the

[32] Inclusive *or* interpretation is a potential confound which may lower the rating of the strength of free choice inferences. For example, participants might very likely interpret the sentence, *Marie is allowed to take Algebra or Literature*, as that Marie is allowed to take Algebra, and she is allowed to take Literature, and she is also allowed to take Algebra and Literature. If without excluding the inclusive *or* interpretation, participants might think that it is not always the case that Marie has to choose one of the courses, because she is also allowed to take both of them. As a result, they might give a lower rating to the free choice inference.

responses of the item associated with *some*. For those items, participants took significantly longer time to make responses associated with scalar implicatures. Third, the response time-windows, whether long (3000ms) or short (900ms), had no significant influence on the derivation rate of free choice inferences. In both types of response time-window, the average derivation rate of free choice inferences was around 70%. This result is at odds with the processing pattern of the scalar implicatures drawn from *some* observed by Bott & Noveck (2004). The results from Bott & Noveck (2004) indicate that the derivation rate of scalar implicatures in the short-tag condition was significantly lower than that in the long-tag condition. Based on the results, Chemla & Bott (2014) argue that there is a discrepancy between the processing pattern of free choice inferences and that of scalar implicatures. However, they do not make any strong claim about the derivation mechanism of free choice inferences. They suggest that the difference in the processing pattern between the two types of inferences could be attributed to the difference in the accessibility of alternatives. The alternatives that are needed for deriving free choice inferences are individual disjuncts which are explicitly given in corresponding disjunctions, while the alternative of *some* (i.e., *all*) needs to be retrieved from lexicon. The lower accessibility of the alternative of *some*, to some extent, might explain why there was a delay in derivation.

In addition, Tieu, et al (2015) conducted a language acquisition experiment which examined whether there is a similarity between the derivation of free choice inferences and the derivation of scalar implicatures among Mandarin children. A scenario verification task was used as the paradigm. At the beginning of the task, the children were informed by Mr. Owl, who had the full knowledge about the rules, that *Kung Fu Panda was only allowed to push the green car*. Then a puppet uttered a target sentence such as *Kung Fu Panda may push the green car or the orange car*. The children were asked to judge whether the sentence uttered by the puppet is true or false. If only the logical interpretation of the sentence was derived, the sentence should be judged as true; however, if the free choice inference was derived, the sentence should be judged as false. The derivation rate of free choice inferences was indicated by the rejection rate of sentences. The results of the experiment show that the derivation rate of free choice inferences among children was 91%, and it was much higher than Children's derivation rate of scalar implicatures, which was only around 18%. Therefore, Tieu, et al conclude that children's processing of free choice inferences and scalar implicatures are not uniformed.

To sum up, previous experimental studies on free choice inferences drawn from disjunction embedded under deontic possibility modals suggest that there are two discrepancies in the processing pattern between free choice inferences and scalar implicatures. First, free choice inferences were very frequently derived, while scalar implicatures were only optionally derived. Second, the derivation of scalar implicatures was found to be delayed compared with the derivation of logical interpretations, while the derivation of free choice inferences was not delayed.

In following sections, I will first elucidate how I obtained the processing data of inferences drawn from disjunction under deontic modals in a picture-sentence binary judgment task (Section 5 and Section 6). Then I will discuss whether the processing pattern of the inferences observed under my paradigm is similar as or different from the processing pattern of scalar implicatures observed in previous studies, and whether the processing pattern of free choice inferences observed in this study is similar as that observed in previous studies (Section 7).

4 Research Questions and Hypotheses

Let's first quickly recap what I aim to investigate in this study. The focus of this study is to understand how *may/or* sentences and *must/or* sentences are interpreted and how the interpretation of them are computed in cognition. As is shown in (35), the interpretation of *may/or* sentences and *must/or* sentences is associated with three meaning components: exhaustivity inferences, free choice inferences and exclusive *or* inferences. Experimentally, it is relatively clear that free choice inferences should be available for *may/or* sentences (see Section 3.2), however, it still remains unclear whether free choice inferences are equally available for *must/or* sentences and whether exhaustivity inferences and exclusive *or* inferences are available for both types of sentences. In addition, we also only know very little about the processing time-courses of the inferences drawn from *may/or* sentences and *must/or* sentences.

(33) $\Diamond (A \vee B)$ / $\Box (A \vee B)$

a. exhaustivity inference: $\{\neg \Diamond c\text{: } c \notin [[A]] \ \&\ c \notin [[B]]\}$

b. free choice inference: $\Diamond A \wedge \Diamond B$

c. exclusive *or* inference: $\neg \Diamond (A \wedge B)$

In literature, while all theoretical studies uniformly predict that free choice inferences should be available for both *may/or* sentences and *must/or* sentences, they have discrepancies in predicting whether exhaustivity inferences and exclusive *or* inferences should be available for both types of sentences as well. Some studies (i.e., conjunctive analysis) predict that exhaustivity inferences and exclusive *or* inferences should be available for both *may/or* sentences and *must/or* sentences, so both types of sentences have a tendency to express strong permission. On the contrary, some studies (i.e., sets analysis) predict that while exclusive *or* inferences are optionally computed for both *may/or* sentences and *must/or* sentences, exhaustivity inferences are only available for *must/or* sentences but not for *may/or* sentences. Based on this, *may/or* sentences have a potential to express weak permission, while *must/or* sentences have a potential to express strong permission. Furthermore, while all theoretical studies agree that exclusive *or* inferences should be computed similarly as scalar implicatures, and exhaustivity inferences should be parts of logical meanings, they disagree with each other in predicting the derivation mechanism of free choice inferences. Some of them (i.e., *scalar implicature* accounts) predict that free choice inferences should be derived as a type of scalar implicatures, while some (i.e., semantic accounts) predict that free choice inferences should be derived as logical interpretations.

Based on the discrepancies and similarities in the assumptions of theoretical studies, if we want to figure out the exact interpretation of *may/or* sentences and *must/or* sentences and the derivation mechanism of them, in general, we need to investigate three things:

(34) a. Whether and to what extent exhaustivity inferences, free choice inferences and exclusive *or* inferences are available?

b. What is the derivation mechanism of exhaustivity inferences, free choice inferences and exclusive *or* inferences? Or more specifically, whether exhaustivity inferences, free choice inferences and exclusive *or* inferences are derived as scalar implicatures or as parts of logical meanings?

c. Is there a difference between *may/or* sentences and *must/or* sentences in the availability and the derivation mechanism of exhaustivity inferences, free choice inferences and exclusive *or* inferences?

In experiments, whether and to what extent a specific inference is available for a sentence can be reflected by derivation rate. Bott & Noveck (2004) and Chevallier et al (2008) suggest that the derivation of scalar implicatures should be optional and delayed compared with that of logical meanings (see Section 3). This means that if an inference is a scalar implicature, we would expect the derivation rate of it to be moderate (i.e., ideally, around 50%). More importantly, if an inference is a scalar implicature, we would expect the derivation of it takes more time than the derivation of a logical meaning. Therefore, by examining the processing time-course in addition to the derivation rate, we can possibly know whether an inference is a scalar implicature. Based on these, I further propose three research questions for my experiment. (35a) sheds light on (34a), (35b) sheds light on (34b), and (35c) sheds light on (34c).

(35) a. What are the derivation rates of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *may/or* sentences and *must/or* sentences?

b. What are the processing time-courses of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *may/or* sentences and *must/or* sentences?

c. Is there a difference between *may/or* sentences and *must/or* sentences in derivation rates and processing time-courses of exhaustivity inferences, free choice inferences and exclusive *or* inferences?

Based on the discussions in Section 2.2.3, Section 2.3.3 and Section 3.1, I propose following hypotheses[33]:

(36) <u>Hypothesis One</u>

If *may/or* sentences and *must/or* sentences are computed under the derivation mechanism for scalar implicatures (Fox, 2007; Alonso-Ovalle, 2006), based on Bott & Noveck (2004) and Chevallier et al (2008),

a. The derivation rates of exhaustivity inferences should be near 100%. The processing time associated with them should be very similar as that associated with logical meanings.

b. The derivation rates of free choice inferences should be moderate (i.e., ideally around 50%). The processing time associated with them should be longer than that of logical meanings. In addition to this, for *may/or* sentences, the processing time associated with free choice inferences should be longer than that associated with exclusive *or* inferences (because free choice inferences are assumed to be derived as secondary implicatures).

c. The derivation rate of exclusive *or* inferences of *may/or* sentences should be moderate (i.e., ideally around 50%), and the derivation rate of exclusive *or* inferences of *must/or* sentences should be near 0%. The processing time associated with exclusive *or* inferences should be longer than that associated with logical meanings.

[33] Please notice that if I do not explicitly mention that there should be a difference between *may/or* sentences and *must/or* sentences in the prediction of a specific inference, it means that I assume that there should be no difference between the two types of sentences in this aspect.

Hypothesis Two

If *may/or* sentences and *must/or* sentences are conjunctions of modal propositions containing covert presuppositions (Geurts, 2005),

a. The derivation rates of exhaustivity inferences should be near 100%. The processing time associated with them should be very similar as that associated with logical meanings.

b. The derivation rates of free choice inferences should be near 100%[34]. The processing time associated with them should be very similar as that associated with logical meanings.

c. The derivation rates of exclusive *or* inferences should be moderate, i.e., ideally around 50%. The processing time associated with them should be longer than that associated with logical meanings.

Hypothesis Three

If *may/or* sentences and *must/or* sentences involve modals operating over sets of alternatives introduced by disjunction (Simons, 2004),

a. The derivation rate of exhaustivity inferences of *may/or* sentences should be near 0%, and the derivation rate of exhaustivity inferences of *must/or* sentences should be near 100%. The processing time associated with exhaustivity inferences should be very similar as that associated with logical meanings.

b. The derivation rates of free choice inferences should be near 100%. The processing time associated with them should be very similar as that associated with logical meanings.

c. The derivation rates of exclusive *or* inferences should be moderate, i.e., ideally around 50%. The processing time associated with exclusive *or* inferences should be longer than that associated with logical meanings.

[34] Semantic accounts (e.g. Geurts, 2005; Simons, 2004) suggest that free choice inferences are preferred logical interpretations of *may/or* sentences and *must/or* sentences.

5 Experiment

This study primarily concerns two issues: the availability and the derivation mechanism of exhaustivity inferences, free choice inferences and exclusive *or* inferences associated with *may/or* sentences and *must/or* sentences (see (34)). As is mentioned in Section 4, the availability of an inference can be measured by derivation rate. Experimentally, one of the most frequently adopted methods to obtain the derivation rate of an inference is to combine the sentence from which this specific inference may be drawn with a situation that runs against this inference, and then examine the rejection rate of the sentence (see the experimental paradigm of Chevallier et al, 2008). If the inference can be drawn from the sentence, we would expect the sentence to be rejected because it is a false description of the situation. Based on this, I chose the picture-sentence binary judgment task as my experimental paradigm. The picture-sentence binary judgment task is widely adopted to detect the existence of a certain type of inferences (see Geurts & Pouscoulous, 2009; Singh, et al., 2015). The derivation mechanism of an inference can be indirectly reflected by the cost of cognitive resources (more specifically, scalar implicatures impose a load in working memory, while logical meanings do not). The consumption of cognitive resources is accompanied by an increase of processing time. In online picture-sentence binary judgment tasks, the processing time of an inference drawn from a sentence can be measured as the reaction time of rejecting the sentence when it is combined with a picture that is incompatible with its inference. To conclude, two types of data are crucial for answering the research questions in (35): the rejection rates of *may/or* sentences and *must/or* sentences that are combined with the situations incompatible with each of the three types of inferences under investigation, and reaction times associated with the rejection of the sentences. In this section, I first explain my experimental paradigm (Section 5.1), then I present the experiment I designed for collecting the experimental data (Section 5.2-5.4).

5.1 A Lottery Machine Paradigm

I created a "lottery machine" paradigm, which involved an online picture-sentence binary judgment task, to obtain the experimental data. The online picture-sentence binary judgment task was designed on ZEP[35]. *Waar* ("true")/*onwaar* ("false") responses and reaction times were recorded. I separately examined the derivation rate and the reaction time of each of the three types of inferences (i.e., exhaustivity inferences, free choice inferences, and exclusive *or* inferences) in three different conditions (see details in Section 5.2.1). Figure 5.1 illustrates the experimental set-up of one of the items associated with the examination of free choice inferences drawn from *may/or* sentences.

[35] ZEP is an open-source application for implementing and running psycholinguistic experiments. It can be used for many different types of experiments and other applications. Development of ZEP began at the Utrecht Institute of Linguistics, Utrecht University. More information about ZEP can be found at https://www.beexy.nl/

Figure 5.1 Set-up for Examining Free Choice Inferences Associated with *May/or* Sentences

Notes

(1) Het kind mag een badmintonracket of een shuttle kopen.
the child may a badminton racket or a shuttlecock buy
"*The child may buy a badminton racket or a shuttlecock.*"

(2) The amount of cash prize a child has been awarded is indicated in green color in the small black square on the right hand side of the lottery machine. *Prijs* means "prize" in English. In this case, the cash prize the child has been awarded is 6 euros.

(3) *Onwaar* means "false" in English; *waar* means "true" in English.

This is a picture-sentence binary judgment task, in which participants were asked to judge whether a sentence is true or false based on the picture and the cover story I provided at the very beginning of the task. The purpose of having the cover story is to create a context upon which *mogen* ("may") and *moeten* ("must") could be interpreted deontically instead of epistemically. The cover story associated with *must/or* sentences was slightly different from the cover story associated with *may/or* sentences. In the cover story[36] designed for both *may/or* sentences and *must/or* sentences, I conveyed following information: "every picture in this experiment will show a lottery machine for children. After a child wins a lottery game, the small screen on the right hand side of the machine will display the total amount of cash prize the child has been awarded. The central screen of the machine will display six different items. The price and availability of the items are displayed below each one of the items. The price is indicated in Euros. A green light indicates an available item and a red light indicates that the item is not available for purchase. The price of the items and their availability as well as the amount of cash prize the child has been awarded all determine what items the child is allowed to buy from the lottery machine". By doing this, I created a context for expressing deontic possibility. In the cover story designed for *must/or* sentences, I conveyed one additional piece of information: "the child has to buy something from the lottery machine with the cash prize he/she has been awarded, otherwise the machine will be unable to load the

[36] The cover story in Dutch can be found in Appendix.

next lottery game". By doing this, I created a context for expressing deontic necessity.

If we interpret the picture in Figure 5.1 under the cover story, the picture indicates that the child is only allowed to buy a shuttlecock because it is both available and affordable. He/she is not allowed to buy a badminton racket because the price of a badminton racket surpasses the cash prize he has been awarded. He/she is also not allowed to buy any of the items with a red light beneath because the red light indicates unavailability, and unavailability plays a role in determining what a child is allowed to buy. Please notice that for every item associated the examination of free choice inferences, I always guaranteed that the situation depicted by the picture was compatible with the exhaustivity inference of the corresponding sentence, so that the potential confound which might influence the derivation rate of free choice inferences was eliminated[37] (the similar design can also be found in Chemla, 2009).

The sentence, if translated into English, should be that *the child is allowed to buy a badminton racket or a shuttlecock*. It has two interpretations. First, it has a fairly weak meaning, which is that the child is allowed to buy at least one thing among a badminton racket and a shuttlecock. Second, it has a free choice inference that the child is allowed to buy a badminton racket and he/she is also allowed to buy a shuttlecock. If participants only compute the weak meaning, they should judge the sentence as the correct description of the picture. However, if they compute the free choice inference, they should judge the sentence as the incorrect description of the picture. This is to say, *onwaar* ("false") responses are symbols of the derivation of free choice inferences. The percentage of *onwaar* ("false") responses indicates the derivation rate of free choice inferences. In addition, based on Bott & Noveck (2004), if free choice inferences are derived as scalar implicatures, the reaction time associated with *onwaar* ("false") responses should be longer than that associated with *waar* ("true") responses.

For each item in the task, a picture depicting a lottery machine, such as the one presented in Figure 5.1, was firstly presented on the computer screen for 500ms. After 500ms, a plus sign ("+") would occur at the beginning of the sentence bar beneath the picture. Participants were instructed that if they press the middle button on the button box, the plus sign would be replaced by the first chunk of a sentence. All sentences involved the self-paced reading. All target sentences (i.e., *may/or* sentences and *must/or* sentences) were cut into five chunks. The first chunk contained the subject NP, *het kind* ("the child"). The second chunk contained a deontic modal (e.g. *mag*/ "may"). The third chunk contained the first disjunct (e.g. een badmintonracket/"*a badminton racket*"). The fourth chunk contained the disjunctive coordinator *of* ("or"). The fifth chunk contained the rest parts of the sentence, i.e., the second disjunct (e.g. een shuttle/ "*a shuttlecock*") and the verb *kopen* ("buy"). The sentence chunks could continuously show up by pressing the middle button. Once the entire sentence was presented on the screen, participants were required to decide whether the sentence is *waar*

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[37] More specifically, assume that a picture, which depicts the situation that the child is allowed to buy a badminton racket and he/she is also allowed to buy a basketball, is combined with the sentence that *the child may buy a badminton racket or a shuttlecock*. Under this circumstance, there are two possibilities for participants to reject the sentence. First, they might derive the free choice inference which indicates that the child is allowed to buy a badminton racket and he/she is also allowed to buy a shuttlecock, and the free choice inference is incompatible with the picture. Second, they might derive the exhaustivity inference which indicates that the child is not allowed to buy anything other than a badminton racket and a shuttlecock, and the exhaustivity inference is incompatible with the picture. Now we can very easily see what the problem is. Participants might reject the sentence due to the derivation of the free choice inference, and they might also reject the sentence due to the derivation of the exhaustivity inference, but we are unable to know which one is the exact reason that causes them to reject the sentence.

(“true”) or *onwaar* (“false”) by pressing the corresponding left/right button on the button box. The time from the occurrence of the last chunk of the sentence to the pressing of the left/right button was recorded as the reaction time.

5.2 Design and Materials

The experiment used a 2×5 between-subject factorial design. There were two independent variables. One independent variable was the type of deontic modals used in target sentences. It has two levels: *mogen* (“may”) and *moeten* (“must”). Another independent variable was the type of conditions created for target sentences. There were two types of conditions: control conditions (Section 5.2.2) and target conditions (Section 5.2.1). There were two control conditions: the true control condition in which target sentences are absolutely compatible with the situations depicted by corresponding pictures, and the false control condition in which target sentences are absolutely incompatible with the situation depicted by corresponding pictures. There were three target conditions: the exhaustivity condition in which target sentences are incompatible with corresponding pictures if exhaustivity inferences are derived, the free choice condition in which target sentences are incompatible with corresponding pictures if free choice inferences are derived, and the exclusive *or* condition in which target sentences are incompatible with corresponding pictures if exclusive *or* inferences are derived. There were two dependent variables. One dependent variable was *waar* (“true”)/*onwaar* (“false”) responses. Another dependent variable was the reaction time associated with *waar* (“true”)/*onwaar* (“false”) responses.

Since the interpretation of *may/or* sentences may influence the interpretation of *must/or* sentences (especially in the exhaustivity condition and the exclusive *or* condition[38]), I divided the experiment into two versions. In the *may/or* version, I examined whether the three types of inferences under investigation could be drawn from *may/or* sentences. In the *must/or* version, I examined whether the three types of inferences could be drawn from *must/or* sentences. The *may/or* version was different from the *must/or* version in three aspects: first, the cover story in the *must/or* version conveyed one more piece of information than the *may/or* version (see Section 5.1); second, the deontic modal involved in the *may/or* version was *mogen* (“may”), while the deontic modal involved in the *must/or* version was *moeten* (“must”). Third, different practice items were created for the two versions (see Appendix). Except for these, all other things in the two versions were identical.

Altogether there were 60 testing items in each version of the experiment. The summary of the design and the conditions of the testing items can be found in Table 5.1.

Table 5.1 Design and Conditions of Testing Items

	exhaustivity condition	**free choice condition**	**exclusive *or* condition**	**true control condition**	**false control condition**	**total**
the *may/or* version	12	12	12	12	12	60
the *must/or* verision	12	12	12	12	12	60

[38] Some of the theoretical studies (e.g. Simons, 2004; Alonso-Ovalle, 2006) predict the difference between *may/or* sentences and *must/or* sentences in the availability of exhaustivity inferences and exclusive *or* inferences, but none of the theoretical studies predict the difference between *may/or* sentences and *must/or* sentences in the availability of free choice inferences.

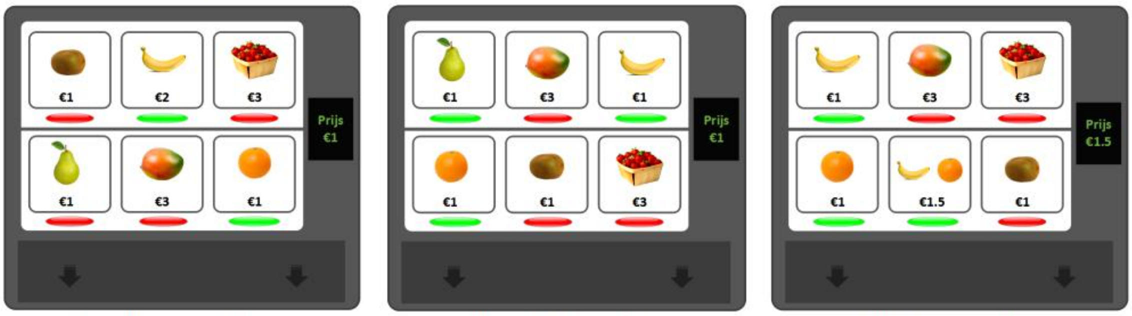
5.2.1 Target Conditions

In each version of the experiment, there were three target conditions: the exhaustivity condition, the free choice condition, and the exclusive *or* condition. Figure 5.2 below illustrates one of the items used in each of the target conditions. More example items can be found in Appendix. All target sentences in the *may/or* version were in the form of *the child may buy* NP_1 *or* NP_2 (i.e., *het kind mag* NP_1 *of* NP_2 *kopen* in Dutch), and all target sentences in the *must/or* version were in the form of *the child must buy* NP_1 *or* NP_2 (i.e., *het kind moet* NP_1 *of* NP_2 *kopen in Dutch*). For each target sentence, three pictures corresponding to three target conditions were created.

Figure 5.2 Items of Target Conditions

The statement in *may/or* version
Het kind mag een sinaasappel of een banaan kopen.
("The child may buy an orange or a banana.")

The statement in *must/or* version
Het kind moet een sinaasappel of een banaan kopen.
("The child must buy an orange or a banana.")



free choice condition
correct response: T/F

exhaustivity condition
correct response: T/F

exclusive *or* condition
correct response: T/F

The free choice condition was designed to examine the derivation of free choice inferences. Since the detailed explanation of this condition has been given in Section 5.1, I prefer not to repeat it here. The exhaustivity condition was designed to examine the derivation of exhaustivity inferences. Based on the cover story, the picture in this condition indicates that the child is allowed to buy a pear, that he/she is allowed to buy a banana, and that he/she is allowed to buy an orange, but he/she is only allowed to buy one of them. Here I guaranteed that the situation described by the picture is compatible with both the free choice inference and the exclusive *or* inference of the corresponding sentence, so that the potential confounds were eliminated to the largest extent (see detailed explanation in Footnote 37). The picture was combined with the sentence that *the child may buy an orange or a banana* in the *may/or* version and the sentence that *the child must buy an orange or a banana* in the *must/or* version. If the exhaustivity inference that the child may not buy anything other than an orange or a banana was derived, participants would judge the sentences as the incorrect descriptions of the situation depicted by the picture, because the exhaustivity inference suggests that the child is not allowed to buy a pear. However, if the exhaustivity inference was not derived, the sentences should be compatible with the additional permission to buy a pear. Under this circumstance, participants would judge the sentences as the correct description of the picture.

The exclusive *or* condition was designed for examining the derivation of exclusive *or* inferences. Based on the cover story, the picture in this condition indicates that the child is allowed to buy an orange, that he/she is allowed to buy a banana, and that he/she is also allowed to buy both an orange and a banana. However, he/she is only allowed to choose either an orange, or a banana, or both to buy. In addition, he/she is not allowed to buy anything other than an orange and a banana. Similar as the manipulation to the free choice condition and the exhaustivity condition, I guaranteed that free choice inferences and exhaustivity inferences would not be potential confounds. The sentences combined with the picture were that *the child may/must buy an orange or a banana*. If exclusive *or* inferences were drawn from the sentences, participants would judge the sentences as the incorrect descriptions of the picture, because the exclusive *or* inferences suggest that there should be no permission for buying both fruits. By contrast, without the derivation of exclusive *or* inferences, participants should judge the sentences as the correct descriptions of the picture.

In conclusion, in all three target conditions, if inferences under investigation were derived, participants should judge target sentences as incorrect descriptions of the corresponding pictures. So *false* responses are indicators of the derivation rates of the inferences I aim to examine. If a certain type of inferences was a strongly preferred logical meaning, we would expect the percentage of *false* responses associated with it to be near 100%. Furthermore, we would also expect that the *false* responses associated with it should not be delayed, if compared with the responses in control conditions in which only logical interpretations were involved in making judgments. However, if a certain type of inferences was derived as scalar implicatures, the percentage of *false* responses associated with it should be moderate (ideally around 50%), and the reaction time associated with the *false* responses should be longer than the reaction time of the items in control conditions.

5.2.2 Control Conditions

In Figure 5.3, I illustrate two of the items that were respectively used in the true control condition and the false control condition.

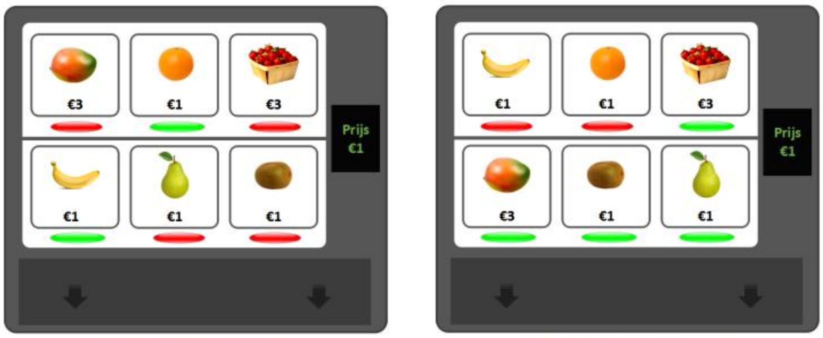
Pictures in the true control condition were always compatible with all three types of inferences under investigation. For example, the picture in the true control condition illustrated in Figure 5.3 satisfies the free choice inference of the corresponding target sentences, which is that the child is allowed to buy an orange and he/she is also allowed to buy a banana. It also satisfies the exhaustivity inference, which is that the child is not allowed to buy anything other than an orange and a banana. Furthermore, it satisfies the exclusive *or* inference, which is that the child is not allowed to buy both an orange and a banana. Therefore, participants should always judge the sentences in this condition as the correct descriptions of the pictures. Ideally speaking, if participants did not make any mistake during the experiment, we would expect the percentage of *false* responses in this condition to be 0%.

Conversely, pictures in the false control condition were always incompatible with the corresponding target sentences. For example, the picture in the false control condition illustrated in Figure 5.3 depicts a situation whereby the child is not allowed to buy an orange and he/she is also not allowed to buy a banana, while the corresponding sentences suggest that there should be at least a permission to buy one of the two fruits. Therefore, ideally, we would expect the percentage of *false* responses in this condition to reach 100%.

Figure 5.3 Items of Control Items

The statement in *may/or* version
Het kind mag een sinaasappel of een banaan kopen.
("The child may buy an orange or a banana.")

The statement in *must/or* version
Het kind moet een sinaasappel of een banaan kopen.
("The child must buy an orange or a banana.")



true control condition
correct response: T

false control condition
correct response: F

Control conditions had two important functions. First, control conditions were used to examine whether participants performed properly in the experiment, because the items in these conditions have unambiguous truth values, i.e., items in true condition are constantly true and items in false condition are constantly false. If a participant did not understand the picture-sentence judgment task correctly, or if he/she was not attention-focusing during the experiment, the percentage of his/her *false* responses in the true control condition would be much higher than 0% and the percentage of his/her *false* responses in the false control condition would be much lower than 100%. Therefore, I used the accuracy rates in control conditions as a way to detect invalid data (see Section 6.1). Second, I used the reaction time associated with *true* responses in the true control condition and the reaction time associated with *false* responses in the false control condition as baselines for detecting whether the derivation of the three types of inferences under investigation were delayed (see Section 6.2), because only logical meanings were involved in the judgment-making of the items in control conditions. If the reaction time in a target condition was longer than that in control conditions, then it means that the inference derivation in this condition was delayed. On the contrary, if the reaction time in a target condition was very similar or even shorter than that in control conditions, then it means that the inference derivation in this condition was not delayed.

5.2.3 Practice Items and Filler Items

For each version of the experiment, six practice items were created. In half of the practice items, the sentences did not correctly describe the corresponding pictures, while in the other half of the practice items, the sentences correctly described the corresponding pictures. Practice items were presented to participants as soon as they finished reading the instructions and the cover story. The practice items had two functions. First, they got participants familiarized with the picture-sentence binary judgment task. Second, they examined participants' understanding and enhanced participants' memory of the cover story. All practice items are given in Appendix. Furthermore, in order to conceal the experimental purposes, I added 70 filler items in each version of the experiment. The filler items consist of six sentence types, represented by the sentences in Table 5.2. More examples of filler items can be found in Appendix.

Table 5.2 Examples of Filler Items

sentence types	true control condition	false control condition	scalar implicature condition	total
Some types of fruits are available.	4	4	4	12
Some accessories are not available.	4	4	4	12
Both a cucumber and a tomato cost 1 euro.	8	8	-	16
The cheapest item is a lemon.	5	5	-	10
The most expensive item is a scarf.	5	5	-	10
No drink is available.	5	5	-	10

5.2.4 Pseudo-randomized Factors

Four types of factors were pseudo-randomized in the experimental design. First, I randomly assigned participants to different versions of the experiment. Second, I pseudo-randomized *waar* ("true")/*onwaar* ("*false*") responses represented by the left/right buttons on the button box. For half of the participants, the left button on the button box presented *true* responses and the right button presented *false* responses. For the other half of the participants, the left button presented *false* responses and the right button presented *true* responses. Third, I pseudo-randomized the sequence of occurrence of the objects in the pictures. For example, each of the target sentences in Figure 5.2 was matched with three similar pictures. But in each of the three pictures, different fruits occurred in different places of the lottery machine. Fourth, all items in each version of the experiment were pseudo-randomized. The pseudo-randomization of the items guaranteed two things. First, it guaranteed that no sentence of the same type occurred twice in a row. For example, there were not two consecutive *may/or* sentences. Second, it guaranteed that the pictures created for the same sentence were separated from each other, so that they never occurred subsequently.

5.2.5 Overview

The experiment was divided into two versions, the *may/or* version and the *must/or* version. In each version, there were 6 practice items, 60 testing items and 70 filler items. In total, there were 136 items in each version of the experiment.

5.3 Participants

I recruited 65 participants (aged from 18 to 52 years old) from the Dutch participant database of Utrecht University. All participants are native speakers of Dutch. Among them, 82% are university students and 78% are females. I randomly assigned 40 participants to the *may/or* version of the experiment. And I randomly assigned 25 participants to the *must/or* version of the experiment. Each participant was compensated with 5 euros for participating the experiment.

5.4 Procedures

The experiment was carried out in a phonetic cabin at the Utrecht Institute of Linguistics (UiL OTS). Before the experiment, the experimenter briefly introduced the experiment to participants, but without giving away the real experimental purposes. Then participants were invited to sit comfortably in the cabin and were asked to sign a consent form. After the consent form was returned to the experimenter, the experiment started. The instructions of the experiment were first presented on the computer screen. The instructions informed participants about how to do the picture-sentence judgment task and how to use the button box to make responses. When participants finished reading the instructions, they could turn to the cover story of the task by pressing a random button on the button box. After participants finished reading the cover story, they were presented with 6 practice items. If participants made a wrong response to any of the practice items, the experiment would be terminated. Then the experimenter would come inside of the cabin to check whether participants had any question about the instructions or the cover story. After this, the experiment would be started once again. If a participant failed in passing the practice section for more than twice, he/she could not participate the experiment any more. When participants successfully passed all practice items, they would be notified that they could start the test section. And they were also informed that if they have any question to ask, they should ask it before the start of the test section. Altogether there were 130 items in the test section. When participants finished judging half of the items, they would be notified that they could take a short break. During the test section, participants were not allowed to ask any question. After the test section, the experiment would be ended. The experimenter could then ask participants to briefly comment on the experiment.

6 Results

Two kinds of results are reported in this section: the percentage of *false* responses in each testing condition (Section 6.1), and the reaction time associated with *true* and *false* responses in each testing condition (Section 6.2).

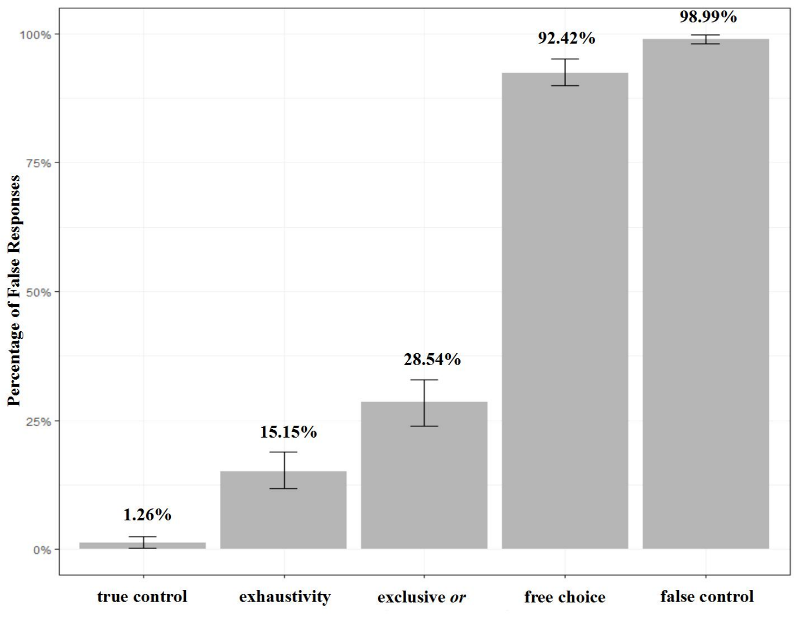
6.1 Percentage of *False* Responses

Before analyzing the response data, I first excluded the data of participants who did not perform properly on items in control conditions[39]. I removed data from 7 participants whose accuracy rates in the false control condition were below 60% in the *may/or* version[40]. All other participants' overall accuracy rates in control conditions were above 90%, so I included all of their data. After excluding the 7 participants, there were data left from 33 participants for the *may/or* version and from 25 participants for the *must/or* version.

I chose to report the percentage of *false* responses in each condition instead of the percentage of *true* responses, because as is mentioned in the end of Section 5.2.1, *false* responses directly reflect the extent to which the inferences under investigation were derived. The higher the percentage of *false* responses was, the higher the derivation rate of the corresponding inferences was.

I submitted the data in the *may/or* version and the *must/or* version to generalized linear mixed models in R (using the *glmer* function in the *lmerTest* package), with sentences, pictures and participants as randomized effects and condition as the fixed effect, to examine whether the difference in condition had a significant influence on responses. As is indicated by the *x*-axis of the graph, the fixed effect, condition, had five levels: the true control condition, the exhaustivity condition, the exclusive *or* condition, the free choice condition and the false control condition.

Figure 6.1 Percentage of *False* Responses in the *May/or* Version



Note: The error bars represent 95% CIs (confidence intervals).

[39] I also checked participants' performance on filler items. All of them had very high accuracy rates on filler items.
[40] The reason why these 7 participants had high error rates in the false control condition in the *may/or* version might be that they did not fully understand the cover story. I further discuss this issue in Section 7.3.

Figure 6.1 shows the percentage of *false* responses in each target condition and control condition in the *may/or* version of the experiment. According to it, the percentage of *false* responses in the free choice condition was the highest among all three target conditions. It indicates that the derivation rate of free choice inferences was as high as 92.42%. On the contrary, the percentage of *false* responses in the exhaustivity condition was the lowest. It indicates that exhaustivity inferences were only derived 15.15% of the times. Furthermore, the percentage of *false* responses in the exclusive *or* condition indicates that the derivation rate of exclusive *or* inferences was 28.54%.

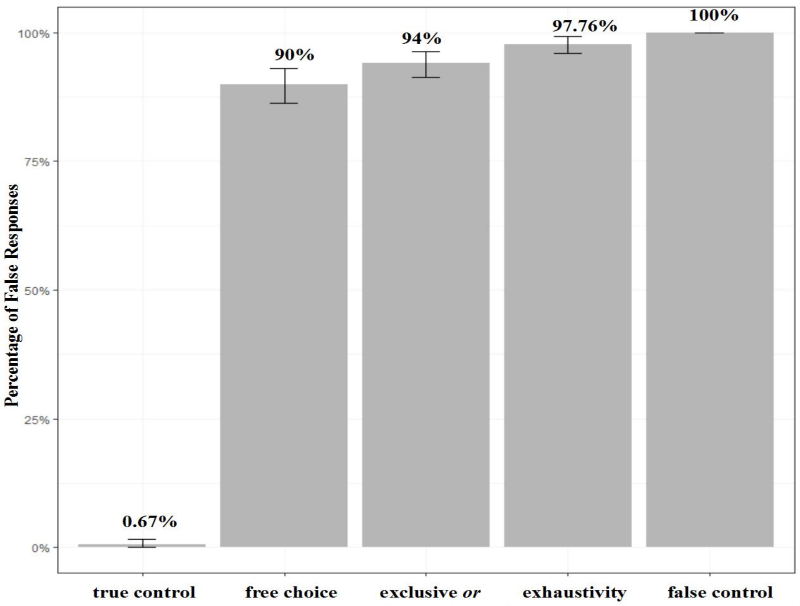
The statistical results suggest that in general, the difference in condition had an significant influence on responses, $F(4) = 104.61$, $p < 0.001$.

More specifically, the percentage of *false* responses in all three target conditions was found to be significantly different from that in the true control (i.e., 1.26%) and that in the false control condition (i.e., 98.99%). The percentage of *false* responses in the free choice condition was significantly higher than that in the true control condition ($\beta = 10.77$, $SE = 0.66$, $z = 16.19$, $p < 0.001$), and it was significantly lower than that in the false control condition ($\beta = -2.36$, $SE = 0.57$, $z = -4.13$, $p < 0.001$). The percentage of *false* responses in the exhaustivity condition was significantly higher than that in the true control condition ($\beta = 3.49$, $SE = 0.53$, $z = 6.60$, $p < 0.001$) and it was significantly lower than that in the false control condition ($\beta = -9.63$, $SE = 0.68$, $z = -14.16$, $p < 0.001$). The percentage of *false* responses in the exclusive *or* condition was significantly higher than that in the true control condition ($\beta = 5.23$, $SE = 0.56$, $z = 9.35$, $p < 0.001$), and it was significantly lower than that in the false control condition ($\beta = -7.90$, $SE = 0.63$, $z = -12.50$, $p < 0.001$).

Furthermore, the percentage of *false* responses in each target condition was significantly different from each other. The percentage of *false* responses in the free choice condition was significantly higher than that in the exhaustivity condition ($\beta = 7.28$, $SE = 0.45$, $z = 16.22$, $p < 0.001$) and that in the exclusive *or* condition ($\beta = 5.54$, $SE = 0.37$, $z = 14.86$, $p < 0.001$). The percentage of *false* responses in the exhaustivity condition was significantly lower than that in the exclusive *or* condition ($\beta = -1.74$, $SE = 0.29$, $z = -6.00$, $p < 0.001$) and that in the free choice condition ($\beta = -7.28$, $SE = 0.45$, $z = -16.22$, $p < 0.001$). The percentage of *false* responses in the exclusive *or* condition was significantly higher than that in the exhaustivity condition ($\beta = 1.74$, $SE = 0.29$, $z = 6.00$, $p < 0.001$), but it was significantly lower than that in the free choice condition ($\beta = -5.54$, $SE = 0.37$, $z = -14.86$, $p < 0.001$).

Figure 6.2 in next page shows the percentage of *false* responses in each target and control condition in the *must/or* version of the experiment.

Figure 6.2 Percentage of *False* Responses in the *Must/or* Version



Note: The error bars represent 95% CIs (confidence intervals).

According to Figure 6.2, the percentages of *false* responses were very high in all three target conditions, which indicates that the derivation rates of free choice inferences, exhaustivity inferences and exclusive *or* inferences were all very high in the *must/or* version. The highest percentage of *false* responses can be found in the exhaustivity condition, which indicates that exhaustivity inferences were derived 97.76% of the times. The percentage of *false* responses in the exclusive *or* condition was the second highest, which indicates that the derivation rate of exhaustivity inferences was 94%. The percentage of *false* responses in the free choice condition was the lowest, which indicates that free choice inferences were derived 90% of the times.

The statistical results suggest that in general the difference in condition had a significant influence on responses, $F(4) = 23.87$, $p < 0.001$. The percentages of *false* responses in all three target conditions were only significantly different from that in the true control condition (i.e., 0.67%), but they were not significantly different from that in the false control condition (i.e., 100%). To state it more accurately, the percentages of *false* responses in the true control condition was significantly lower than that in the free choice condition ($\beta = -9.23$, SE = 1.09, $z = -8.44$, $p < 0.001$), that in the exclusive *or* condition ($\beta = -9.96$, SE = 1.11, $z = -8.97$, $p < 0.001$) and that in the exhaustivity condition ($\beta = -11.25$, SE = 1.17, $z = -9.63$, $p < 0.001$). The percentage of false responses in the false control condition was not significantly higher than that in the free choice condition (($\beta = 19.17$, SE = 2284.02, $z = 0.01$, $p \approx 0.99$), that in the exclusive *or* condition (($\beta = 18.45$, SE = 2284.02, $z = 0.01$, $p \approx 0.99$), and that in the exhaustivity condition (($\beta = 17.15$, SE = 2284.02, $z = 0.01$, $p \approx 0.99$).

6.2 Reaction Times

Before carrying out the statistical analysis, I removed all reaction time data associated with wrong responses in control conditions in both the *may/or* version and the *must/or* version[41]. I

[41] More specifically, I removed all reaction time data associated with *false* responses in the true control condition and all

further removed the outliers which were more than 1.5 IQRs below the first quartile or above the third quartile[42] in both versions. In total, I removed 5.78% of the data points that were outliers in the *may/or* version and I removed 5.47% of the data points that were outliers in the *must/or* version.

I built linear mixed-effects models in R (using the *lmer* function in the *lmerTest* package) to examine how reaction times in the *may/or* version and the *must/or* version were influenced by the fixed effects, i.e., response type and condition, and the randomized effects, i.e., sentences[43], pictures and participants. I applied the square root transformation to reaction time data in both versions to make the data more similar to normal distribution.

Table 6.1 Mean and Stand Deviation of Reaction Times in the *May/or* Version (ms)

	exclusive *or* condition		free choice condition		exhaustivity condition		false control condition	true control condition
	true	*false*	*true*	*false*	*true*	*false*	*false*	*true*
mean	5195	5968	5119	4724	4948	6551	4812	4488
SD	2346	2680	2688	2228	2439	2367	2437	2161

Figure 6.3 Reaction Times in the *May/or* Version

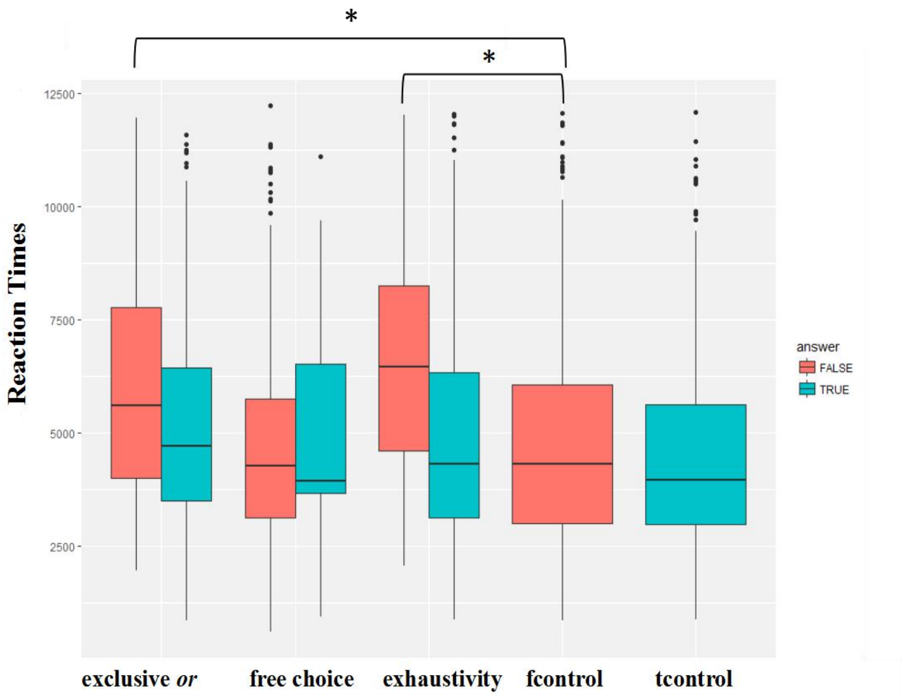


Table 6.1 above shows the mean and the standard deviation of reaction times associated with *true* and *false* responses in each testing condition in the *may/or* version. Figure 6.3 shows the box plot of reaction times in the *may/or* version.

The statistical results suggest that in general the difference in condition and response

reaction time data associated with *true* responses in the false control condition.

[42] The interquartile range (IQR) is known as the middle 50%. Assume that we have 2*n* data points. The first quartile Q_1 equals to the median of the *n* smallest data points, while the third quartile Q_3 equals to the median of the *n* largest data points. If a data point is below Q_1–1.5 IQR or above Q_3 + 1.5 IQR, it is judged as an outlier.

[43] Although all target sentences were of the structure as *het kind mag/moet A of B kopen* ("*the child may/must buy A or B*"), A and B in each target sentence denoted different objects and they were of different lengths.

type had a significant influence on reaction times in the *may/or* version, $F(7) = 11.09$, $p < 0.001$.

The reaction time in the false control condition (M ≈ 4812ms, SD ≈ 2437ms) was slightly longer than that in the true control condition (M ≈ 4488ms, SD ≈ 2161ms), and the statistical results suggest that this difference had a trend towards significance (β = 2.20, SE = 0.99, t = 2.23, p ≈ 0.03[44]).

In the exclusive *or* condition, the reaction time associated with *false* responses (M ≈ 5968ms, SD ≈ 2680ms) was significantly longer than the reaction time in both the false control condition (β = 7.10, SE = 1.61, t = 4.42, p < 0.001) and the true control condition (β = 9.30, SE = 1.60, t = 5.81, p < 0.001). The reaction time associated with *true* responses (M ≈ 5195ms, SD ≈ 2346ms) was also significantly longer than the reaction time in both the false control condition (β = 3.80, SE = 1.10, t = 1.23, p < 0.001) and the true control condition (β = 6.00, SE = 1.10, t = 1.92, p < 0.001). In addition, the reaction time associated with *false* responses in the exclusive *or* condition was longer than that associated with *true* responses in the same condition, and this difference has a trend towards significance (β = 3.30, SE = 1.74, t = 1.88, p = 0.06).

In the free choice condition, the reaction time associated with *false* responses (M ≈ 4724ms, SD ≈ 2228ms) was non-significantly shorter than the reaction time in the false control condition (β = -0.10, SE = 1.00, t = -0.15, p ≈ 0.88), but it had a trend to be significantly longer than the reaction time in the true control condition (β = 2.1, SE = 0.10, t = 2.06, p ≈ 0.04). The reaction time associated with *true* responses (M ≈ 5119ms, SD ≈ 2688ms) was non-significantly longer than the reaction time in both the false control condition (β = 0.20, SE = 2.87, t = 0.08, p ≈ 0.93) and the true control condition (β = 2.40, SE = 2.87, t = 0.85, p ≈ 0.40). In addition, the reaction time associated with *false* responses in the free choice condition was slightly shorter than that associated with *true* responses in the same condition, but this difference was not significant (β = -0.40, SE = 2.90, t = -0.13, p ≈ 0.89).

In the exhaustivity condition, the reaction time associated with *false* responses (M ≈ 6551ms, SD ≈ 2367ms) was significantly longer than the reaction time in both the false control condition (β = 9.60, SE = 2.04, t = 4.68, p < 0.001) and the true control condition (β = 11.8, SE = 2.04, t = 5.78, p < 0.001). The reaction time associated with *true* responses (M ≈ 4948ms, SD ≈ 2439ms) was non-significantly longer than the reaction time in the false control condition (β = 1.70, SE = 1.04, t = 1.61, p ≈ 0.11), but significantly longer than the reaction time in the true control condition (β = 3.90, SE = 1.03, t = 3.76, p < 0.001). In addition, the reaction time associated with *false* responses in the exhaustivity condition was significantly longer than that associated with *true* responses in the same condition (β = 7.90, SE = 2.10, t = 3.75, p < 0.001).

I further compared the reaction times associated with *false* responses in different target conditions. I found that the reaction time associated with *false* responses in the free choice condition was significantly shorter than that in the exclusive *or* condition (β = -7.20, SE = 1.61, t = -4.49, p < 0.001) and that in the exhaustivity condition (β = -9.70, SE = 2.05, t = -4.74, p < 0.001). The reaction time associated with *false* responses in the exclusive *or* condition was slightly shorter than that in the exhaustivity condition, but this difference was

[44] Notes on significance thresholds: the threshold for the overall p-values to reach significance is 0.05, while the threshold for the p-value of between-condition comparisons in a model to reach significance is 0.01.

not significant (β = -2.50, SE = 2.28, t = -1.08, p ≈ 0.28). I also made comparisons between reaction times associated with *true* responses in different target conditions. I found that they were not significantly different from each other. More specifically, the reaction time associated with *true* responses in the exclusive *or* condition was non-significantly longer than that in the free choice condition (β = 3.60, SE = 2.91, t = 1.23, p ≈ 0.22) and that in the exhaustivity condition (β = 2.20, SE = 1.12, t = 1.92, p ≈ 0.06), and the reaction time associated with *true* responses in the exhaustivity condition was also non-significantly longer than that in the free choice condition (β = 1.40, SE = 2.89, t = 0.50, p ≈ 0.62).

I also detected the significant influence of randomized effects. The difference in participants ($X^2(1) < 0.001$, $p < 0.001$) and the difference in sentences ($X^2(1) < 0.001$, $p = 0.001$) significantly influenced reaction times, while the difference in pictures had no significant influence on reaction times ($X^2(1) < 0.001$, $p = 1.00$).

The effect size of the model I built, represented by R^2, was 0.36. It is a large effect size[45], which indicates that the model I built explained 36% of the variance of the reaction time data in the *may/or* version.

Table 6.2 Mean and Stand Deviation of Reaction Times in the *Must/or* Version (ms)

	exclusive *or* condition		free choice condition		exhaustivity condition		false control condition	true control condition
	true	*false*	*true*	*false*	*true*	*false*	*false*	*true*
mean	6811	5013	4579	4715	5785	4659	4795	4520
SD	2892	2594	3002	2387	1973	2326	2673	2160

Figure 6.4 Reaction Times in the *Must/or* version

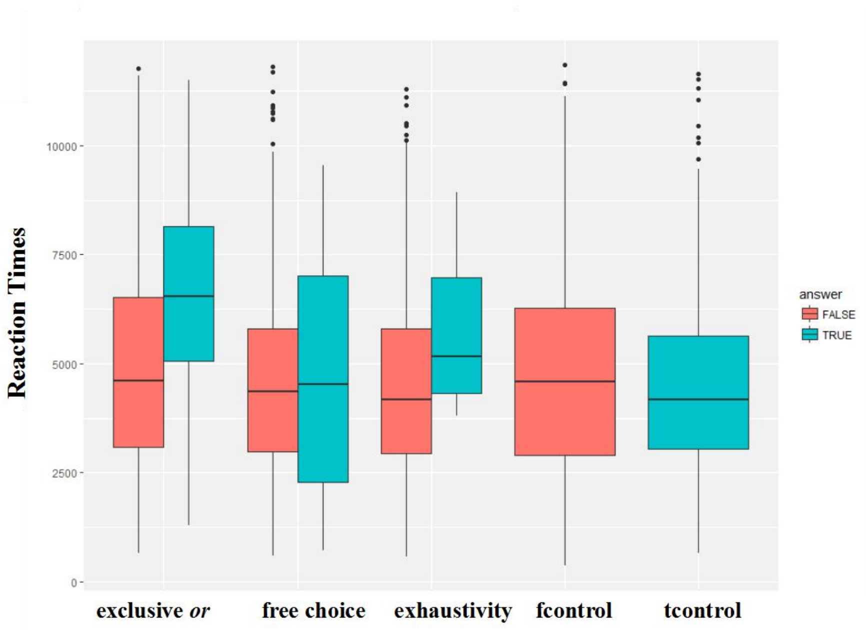


Table 6.2 above shows the mean and the standard deviation of reaction times associated with

45 If R^2 equals to 0.36, then the correlation coefficient *r* equals to 0.60. According to Cohen (1992), if *r* is above 0.5, it indicates a large effect size.

true and *false* responses in each testing condition in the *must/or* version. Figure 6.4 shows the box plot of reaction times in the *must/or* version.

The statistical results suggest that in general the difference in condition and response type had a significant influence on reaction times in the *must/or* version, $F(7) = 6.62$, $p < 0.001$.

The reaction time in the false control condition (M ≈ 4795ms, SD ≈ 2673ms) was slightly longer than that in the true control condition (M ≈ 4520ms, SD ≈ 2160ms), but this difference between them was not significant (β = 1.60, SE = 1.28, t = 1.22, p ≈ 0.23).

In the exclusive *or* condition, the reaction time associated with *false* responses (M ≈ 5013ms, SD ≈ 2594ms) was slightly longer than the reaction time in the false control condition, but this difference was not significant (β = 1.70, SE = 1.30, t = 1.28, p ≈ 0.21). It was also longer than the reaction time in the true control condition, and this difference had a trend to reach significance (β = 3.20, SE = 1.30, t = 2.48, p ≈ 0.02). The reaction time associated with *true* responses (M ≈ 6811ms, SD ≈ 2892ms) was significantly longer than the reaction time in both the false control condition (β = 19.90, SE = 3.59, t = 5.54, p < 0.001) and the true control condition (β = 21.4, SE = 3.59, t = 5.97, p < 0.001). In addition, the reaction time associated with *false* responses in the exclusive *or* condition was significantly shorter than that associated with *true* responses in the same condition (β = -18.20, SE = 3.54, t = -5.14, p = < 0.001).

In the free choice condition, the reaction time associated with *false* responses (M ≈ 4715ms, SD ≈ 2387ms) was non-significantly shorter than the reaction time in the false control condition (β = -0.40, SE = 1.31, t = -0.32, p ≈ 0.75), and it was non-significantly longer than the reaction time in the true control condition (β = 1.10, SE = 1.31, t = 0.87, p ≈ 0.39). The reaction time associated with *true* responses (M ≈ 4579ms, SD ≈ 3002ms) had the trend to be significantly longer than the reaction time in both the false control condition (β = 6.20, SE = 2.93, t = 2.10, p ≈ 0.04) and the true control condition (β = 7.20, SE = 2.93, t = 2.64, p ≈ 0.01). In addition, the reaction time associated with *false* responses in the free choice condition had the trend to be significantly shorter than that associated with *true* responses in the same condition (β = -6.60, SE = 2.87, t = -2.29, p ≈ 0.02).

In the exhaustivity condition, the reaction time associated with *false* responses (M ≈ 4659ms, SD ≈ 2326ms) was non-significantly shorter than the reaction time in the false control condition (β = -0.40, SE = 1.28, t = -0.34, p ≈ 0.74), and it was non-significantly longer than the reaction time in the true control condition (β = 1.10, SE = 1.28, t = 0.88, p ≈ 0.38). The reaction time associated with *true* responses (M ≈ 5785ms, SD ≈ 1973ms) was non-significantly longer than the reaction time in the false control condition (β = 8.60, SE = 5.06, t = 1.69, p ≈ 0.09), but it had the trend to be significantly longer than the reaction time in the true control condition (β = 10.10, SE = 5.06, t = 2.00, p ≈ 0.05). In addition, the reaction time associated with *false* responses in the exhaustivity condition was non-significantly shorter than that associated with *true* responses in the same condition (β = -0.90, SE = 5.02, t = -1.79, p ≈ 0.07).

I further compared the reaction times associated with *false* responses in different target conditions, and I found that they were not significantly different from each other. More accurately, the reaction time associated with *false* responses in the exclusive *or* condition was non-significantly longer than that in both the free choice condition (β = 2.10, SE = 1.33, t =

1.56, $p \approx 0.13$) and the exhaustivity condition ($\beta = 2.10$, SE = 1.30, $t = 1.61$, $p \approx 0.12$). The reaction time associated with *false* responses in the free choice condition was non-significantly longer than that in the exhaustivity condition ($\beta = 0.00$, SE = 1.31, $t = 0.01$, $p \approx 0.99$).

I also detected the significant influence of randomized effects. The difference in participants significantly influenced reaction times, $X^2(1) = 910.71$, $p < 0.001$. The difference in pictures had a trend to significantly influence reaction times, $X^2(1) = 3.83$, $p = 0.05$. The difference in sentences had no significant influence on reaction times, $X^2(1) = 3.31$, $p = 0.07$.

The effect size of the model I built, represented by R^2, was 0.54. It is a large effect size[46], which indicates that the model I built explained 54% of the variance of the reaction time data in the *must/or* version.

[46] If R^2 equals to 0.54, then the correlation coefficient *r* equals to 0.73. According to Cohen (1992), if *r* is above 0.5, it indicates a large effect size.

7 General Discussion

I discussion four things in this section. First, I summarize the important results of the experiment, and discuss how they may answer the research questions I proposed (Section 7.1). Second, I discuss how the experimental results may help us understand the processing of *may/or* sentences and *must/or* sentences (Section 7.2). Third, I discuss the potential issues in the experimental paradigm (Section 7.3). Fourth, I discuss how the experiment in this study may shed light on theoretical studies (Section 7.4).

7.1 Main Findings

In this section, I focus on discussing how the experimental results may answer the research questions I proposed in (35). I first discuss the important results in each version of the experiment, then compare the results of the two versions to see whether *may/or* sentences were interpreted differently from *must/or* sentences. The research questions in (35) are separately repeated in (37), (38) and (39).

(37) a. What are the derivation rates of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *may/or* sentences?

b. What are the processing time-courses of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *may/or* sentences?

I answer the questions in (37) as follows. The *may/or* version of the experiment was designed for examining the derivation rates and processing time-courses of the three types of inferences drawn from *may/or* sentences. The derivation rates of the inferences were reflected by the percentage of *false* responses in each target condition in the *may/or* version. The processing time-courses of the inferences were mainly reflected by the comparisons of the reactions times between each target condition and the false control condition in the *may/or* version.

I found a very high percentage of *false* responses in the free choice condition (≈ 92%), and I found low percentages of *false* responses in both the exhaustivity condition (≈ 15%) and the exclusive *or* condition (≈ 30%). The results related to *false* responses indicate that when participants interpreted *may/or* sentences, they had a very high derivation rate of free choice inferences, but they had low derivation rates of both exhaustivity inferences and exclusive *or* inferences.

I further found that the reaction times associated with *false* responses in both the exhaustivity condition (6551ms) and the exclusive *or* condition (5968ms) were significantly longer than that in the false control condition (4812ms). Compared with this, the reaction time associated with *false* responses in the free choice condition (4724ms) was slightly shorter than that in the false control condition, but this difference was not significant. I also found that the reaction time associated with *false* responses in the exclusive *or* condition (5968ms) had a trend to be significantly longer than that associated with *true* responses in the same condition (5195ms), and the reaction time associated with *false* responses in the exhaustivity condition (6551ms) was significantly longer than that associated with *true* responses in the same condition (4948ms). However, the reaction time associated with *false* responses in the free choice condition (4724ms) was not significantly shorter than that associated with *true* responses in the same condition (5119ms). The reaction time results, therefore, indicate that the derivation of free choice inferences of *may/or* sentences was not more time-consuming than the derivation of logical interpretations, but the derivation of exhaustivity inferences and exclusive *or* inferences of *may/or* sentences were more time-consuming than the derivation of logical interpretations.

(38) a. What are the derivation rates of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *must/or* sentences?
b. What are the processing time-courses of exhaustivity inferences, free choice inferences and exclusive *or* inferences drawn from *must/or* sentences?

I answer the questions in (40) as follows. In the *must/or* version of the experiment, which was designed for examining the derivation rates and processing time-courses of the inferences drawn from *must/or* sentences, I found high percentages of *false* response in the free choice condition (= 90%), the exclusive *or* condition (= 94%) and the exhaustivity condition (≈ 98%). The results of response data indicate that participants had very high derivation rates of free choice inferences, exclusive *or* inferences and exhaustivity inferences.

I further found that in the *must/or* version, the reaction times associated with *false* responses in the free choice condition (4715ms), the exclusive *or* condition (5013ms) and the exhaustivity condition (4659ms) were similar to each other, and all of them were not significantly different from the reaction time in the false control condition (4795ms). Therefore, the response time results indicate that the derivation of exhaustivity inferences, free choice inferences and exclusive *or* inferences of *must/or* sentences was similarly not more time-consuming than the derivation of logical interpretations.

(39) Is there a difference between *may/or* sentences and *must/or* sentences in derivation rates and processing time-courses of exhaustivity inferences, free choice inferences and exclusive *or* inferences?

I answer the question in (39) as follows. Free choice inferences drawn from *may/or* sentences and *must/or* sentences do not seem to be different from each other. The derivation rates of free choice inferences drawn from *may/or* sentences and *must/or* sentences were similarly high, i.e., at least 90%. And the derivation of free choice inferences drawn from both types of sentences was similarly not more time-consuming than the derivation of logical interpretations. The crucial difference between the two types of sentences lies in exhaustivity inferences and exclusive *or* inferences. The derivation rates of exhaustivity inferences and exclusive *or* inferences of *may/or* sentences (i.e., not more than 30%) were much lower than those of *must/or* sentences (i.e., above 90%). In addition, while the derivation of exhaustivity inferences and exclusive *or* inferences of *may/or* sentences was more time-consuming than the derivation of logical interpretations, the derivation of those two types of inferences of *must/or* sentences were not more time-consuming.

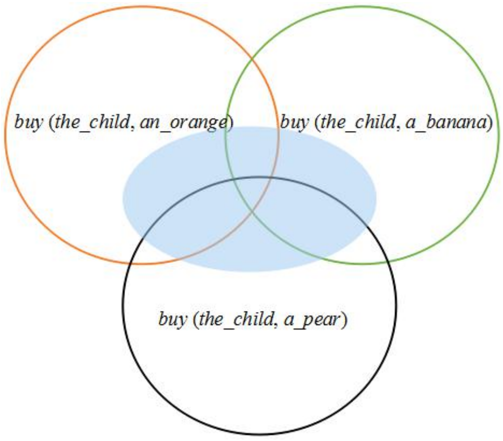
7.2 Processing *May/or* Sentences and *Must/or* Sentences

If we want to know how *may/or* sentences and *must/or* sentences are processed, we should first figure out the derivation mechanism of different meaning components of the two types of sentences. More specifically, it is of a great importance to know to what extent exhaustivity inferences, free choice inferences and exclusive *or* inferences can be derived from *may/or* sentences and *must/or* sentences, and whether their derivation is time-consuming. As is mentioned in Section 2.4, the derivation of logical meanings is typically assumed to be by default and not time-consuming. As is mentioned in Section 3, Bott & Novek's (2004) and Chevallier et al's (2008) experiments similarly suggest that implicature derivation under situation-sentence binary judgment tasks should be optional and time-consuming. Based on these, we could possibly tell the derivation mechanism of the inferences under investigation. In this section, I separately discuss the inferences drawn from *may/or* sentences and *must/or* sentences.

7.2.1 *May/or* Sentences Granting Weak Permission

Based on the overall derivation rates of the three types of inferences in the *may/or* version of the experiment, we could say that in general, *may/or* sentences such as (40), had a tendency to grant weak permission. More specifically, the set of deontically accessible worlds of (40) not only includes a set of worlds in which the child only buys an orange and a set of worlds in which the child only buys a banana, but also allows for the existence of a set of worlds in which the child buys both an orange and a banana, and the existence of a set of worlds in which the child buys a fruit, such as a pear, which is not indicated by the two individual disjuncts.

(40) The child may buy an orange or a banana.



Notes
The orange circle denotes a set of worlds in which the child buys an orange.
The green circle denotes a set of worlds in which the child buys a banana.
The black circle denotes a set of worlds in which the child buys a pear.
The blue shadow denotes the set of deontically accessible worlds.

In order to have a clearer idea about to what extent *may/or* sentences were interpreted as expressions that grant weak permission, I further looked into individual differences in interpreting *may/or* sentences. Participants were categorized into the groups as is shown in Table 7.1.

Table 7.1 Individual Difference in Interpreting *May/or* Sentences

Group	Subgroup	Number of Participants
Low-FC Group	-	5
High-FC Group	Weak Permssion Group (WP Group)	19
	Strong Permission Group (SP Group)	5
	Neither Weak Nor Strong Permission Group (NWNSP Group)	4

Note: *FC* is the abbreviation for *free choice inferences*.

Each of the 5 participants in the Low-FC Group had a relatively low derivation rate of free choice inferences, which was between 17% to 50%. Except for these five participants, all other participants (i.e., all participants in the High-FC Group) had very high derivation rates of free choice inferences. Among them, 6 participants derived free choice inferences 92% of the times, and 22 participants derived free choice inferences 100% of the times. I further divided the High-FC Group into three subgroups. All 19 participants in the Weak Permission Group had very low derivation rates of both exhaustivity inferences and exclusive *or* inferences. Among them, 17 participants had 0% derivation rates of both exhaustivity inferences and exclusive *or* inferences, while the rest 2 participants had a 0% derivation rate of exhaustivity inferences and 8% ~ 25% derivation rates of exclusive *or* inferences. All 5 participants in the Strong Permission Group had high derivation rates of both exhaustivity inferences and exclusive *or* inferences. More specifically, all these participants' derivation rates of exhaustivity inferences were between 50% to 92% and all their derivation rates of exclusive *or* inferences were between 92% to 100%. 4 participants who occasionally derived exhaustivity inferences but frequently derived exclusive *or* inferences were categorized into the Neither Weak Nor Strong Permission Group. Their derivation rates of exhaustivity inferences were not higher than 25%, while their derivation rates of exclusive *or* inferences were not lower than 50%. The data indicate that a majority of participants (i.e., 56% or 19/33) always interpreted *may/or* sentences as expressions granting weak permission, while only a small group of participants (i.e., 15% or 5/33) were inclined to interpret *may/or* sentences as expressions granting strong permission.

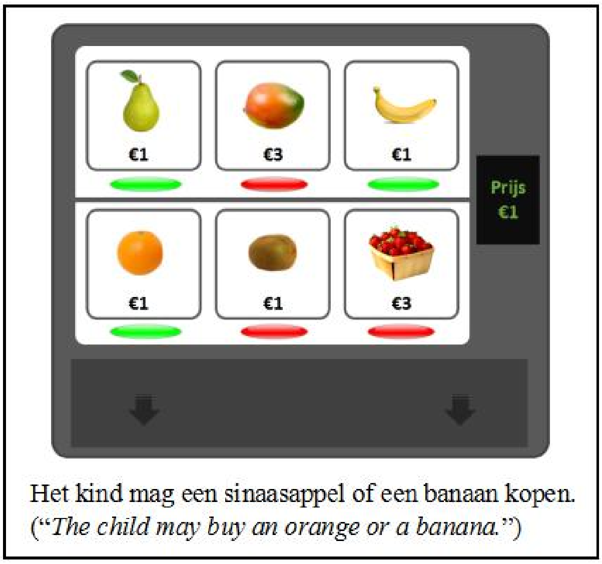
Till now, we have a relatively clear idea about the availability of the three types of inferences drawn from *may/or* sentences. However, the availability alone cannot tell much about the derivation mechanism of the inferences. So next, I combine the processing time-courses of the inferences to discuss whether they were derived as implicatures or as parts of logical meanings.

In my experiment, exhaustivity inferences and exclusive *or* inferences drawn from *may/or* sentences shared very similar features: optional derivation accompanied by an increase of processing time. The optional derivation of them can be reflected in two aspects. First, their overall derivation rates were around 15% and 30% respectively. Second, more than half (i.e., 17/33) of the participants did not derive both inferences, while the rest of the participants had various derivation rates of them. This piece of data gives us a even better idea about the optional derivation: not every participant computed the two types of inferences; and for those participants who computed them, it was not the case that each of them computed each type of the inferences for every occurrence of *may/or* sentences. The time-consuming feature of the two types of inferences can be reflected by the fact that the reaction times associated with the two types of inferences were or tended to be significantly longer than the reaction time associated with logical meanings. The processing patterns of the two types of inferences were very similar as the processing pattern of scalar implicatures observed by previous studies. For example, Chevallier et al (2008) observed that in their situation-sentence binary judgment task, the derivation rate of the scalar implicatures associated with *or* was around 25%; and when the scalar implicatures were derived, the responses were delayed (see Section 3.1). Based on the evidence mentioned above, we can conclude that exhaustivity inferences and exclusive *or* inferences drawn from *may/or* sentences behaved very similarly as scalar implicatures. Then the next question is why they behaved like so?

Exclusive *or* inferences drawn from *may/or* sentences are primarily associated with the occurrence of the disjunctive coordinator, i.e., *of* in Dutch (*or* in English). According to Fox (2007) and Alonso-Ovalle (2006), when interpreting *may/or* sentences, such as *the child may buy an orange or a banana*, if the stronger alternative of *or*, i.e., *and*, is negated, exclusive *or* inferences, such as *the child may not buy an orange and a banana*, can be derived. This computation process is identical as the computation process of scalar implicatures drawn from unembedded plain disjunction. Based on this, it is very easy to understand why exclusive *or* inferences drawn from *may/or* sentences behaved like scalar implicatures.

Compared with this, the reason why exhaustivity inferences drawn from *may/or* sentences also behaved like scalar implicatures is much less apparent. Exhaustivity inferences are derived by negating the options that are not indicated by individual disjuncts. The scalar item, *or*, in *may/or* sentences plays no role in deriving exhaustivity inferences. So exhaustivity inferences cannot be scalar implicatures. Then could they be a more general type of conversational implicatures that share the crucial features with scalar implicatures? Well, I consider it to be highly possible. Let's first recall the type of items that was created for examining exhaustivity inferences.

Figure 7.1 Item in the Exhaustivity Condition in the *May/or* Version



Under our experimental paradigm, the picture in Figure 7.1 conveys the information that the child may buy a pear or a banana or an orange. Or more accurately speaking, the picture suggests that there are three permissible options: a pear, a banana and an orange. The sentence combined with the picture, however, only mentions two permissible options, i.e., an orange and a banana. Here we can clearly notice that the picture and the sentence conveys unbalanced amounts of information, i.e., the sentence is an underinformative description of the situation depicted by the picture. When interpreting the sentence, if participants were sensitive to informativeness and if they assumed that the speaker of the sentence should always convey as much information he/she believes to be true as possible (i.e., the maxim of quantity), they would think that if the speaker knows that the child is also allowed to buy a pear, he/she should have said it. As a result, the quantity implicature of the sentence could be drawn, which implies that the speaker of the sentence believes that the child is not allowed to buy a pear. This quantity implicature is in direct opposition to the situation depicted by the picture, and it has the exactly same type of contents as the inferences named as exhaustivity inferences in this study. Based on this, I think that exhaustivity inferences drawn from *may/or* sentences could be quantity implicatures. If exhaustivity inferences drawn from *may/or* sentences are quantity implicatures, then the time-consuming feature of them could be explained as that the Gricean-like reasoning in general imposes loads to working memory and consumes cognitive resources. The optional derivation of them could be explained in two ways: first, it might be possible that participants did not have enough cognitive resources to compute the exhaustivity inference for every occurrence of *may/or* sentences; second, it might also be possible that participants were very tolerant to underinformativeness (see Katsos & Bishop, 2011).

Free choice inferences drawn from *may/or* sentences seem to be the default interpretations that were not delayed. The frequent derivation of them can reflected by two pieces of evidence. First, the overall derivation rate of free choice inferences was above 90%. Second, around 67% of the participants (i.e., 22/33) derived free choice inferences for all occurrences of *may/or* sentences. The not-delayed derivation of free choice inferences can be reflected by the fact that the reaction time associated with free choice inferences was roughly the same as that associated with logical interpretations. The processing pattern of free choice inferences drawn from *may/or* sentences observed in our experiment was very similar as that observed in previous studies. For example, the derivation rates of free choice inferences were above 90% in van Tiel's (2012) and Chemla's (2009) experiments, and the reaction time associated with free choice inferences was not longer than that associated with logical interpretations in Chemla & Bott's (2014) experiments (see Section 3.2). If free choice inferences are classical scalar implicatures (such as the scalar implicatures drawn from *some*), instead of being derived frequently, they should be of a medium derivation rate. Furthermore, if they are classical scalar implicatures, instead of being derived without a delay in processing time, the derivation of them should be accompanied by an increase of processing time. Based on these, I conclude that there seems to be a difference between the processing pattern of free choice inferences drawn from *may/or* sentences observed in our experiment and the processing pattern of scalar implicatures observed by previous studies (i.e., Bott & Noveck, 2004; Chevallier et al, 2008). Now the question is how should we interpret the difference between free choice inferences and classical scalar implicatures?

One might argue that free choice inferences could be involved with a cost-free derivation process. For example, they could be derived by applying a cost-free exhaustification operator (*exh*) in syntax (see Levinson, 2000). Under this assumption, we could successfully explain the default and not-delayed derivation of free choice inferences, however, we would face difficulties in explaining the optional and delayed derivation of exclusive *or* inferences. According to Fox (2007), exclusive *or* inferences should be derived as early as *exh* is applied for the first time, while free choice inferences can only be derived when *exh* is applied for the second time. Based on this, normally, we would expect exclusive *or* inferences to be derived prior to free choice inferences. Even if we assume that *exh* is cost-free, we would still expect exclusive *or* inferences to be derived at roughly the same time as free choice inferences. However, I actually observed a reversed pattern: deriving exclusive *or* inferences took a much longer time than deriving free choice inferences.

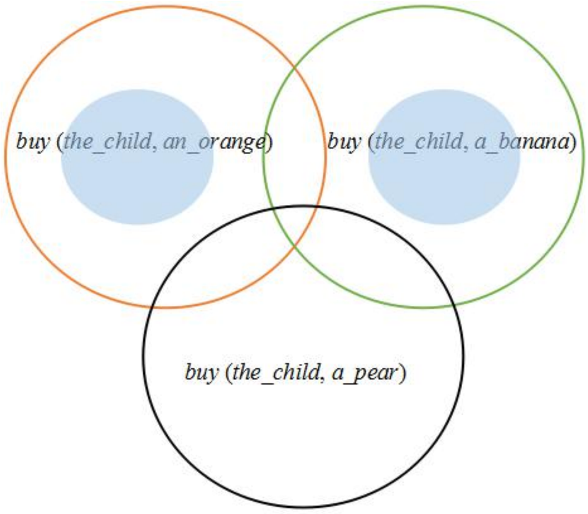
Alternatively, one might further argue that it could be possible that the computation of scalar implicatures does not take time, but the computation of alternatives does. For example, Gualmini et al (2001) found that if alternatives were explicitly given to children, children's ability to derive scalar implicatures was largely improved. So there is a reason to believe that sometimes people do not derive scalar implicatures because they do not have enough resources to retrieve alternatives from lexicon, but not because they do not have enough resources to support the computation of scalar implicatures. This assumption seems to be appealing. Under this assumption, the optional and delayed derivation of exclusive *or* inferences could be explained as that participants needed to consume resources and time to retrieve alternatives from working memory. On the contrary, free choice inferences could be derived frequently without a delay because the alternatives for computing free choice inferences were the two individual disjuncts that were explicitly given in the original sentences. This assumption could nicely explain the difference in free choice inferences and exclusive *or* inferences; however, it faces a crucial problem: how could we explain the delayed and optional derivation of exhaustivity inferences? Similar as free choice inferences, the derivation of exhaustivity inferences was also solely dependent on the two individual disjuncts which were explicitly given. If we assume that implicature computation in general is not time-consuming, then exhaustivity inferences should behave very similarly as free choice inferences. However, I actually found that exhaustivity inferences needed a much longer time to be derived than free choice inferences. Thus, I think it is too risky to assume that implicature computation is not time-consuming.

Based on the above arguments, I think it could be of some difficulty to interpret free choice inferences as a special type of scalar implicatures that are not associated with processing cost. Then is it possible that free choice inferences are preferred logical interpretations of *may/or* sentences (Simons, 2004; Geurts, 2005)? Well, I consider it to be possible. Under this assumption, the derivation of free choice inferences was not time-consuming because normally computing well-formed semantic representations of the sentences (i.e., computing the truth conditions of the sentences) should be automatic and impose no load to working memory. Compared with this, the derivation of exclusive *or* inferences and exhaustivity inferences were time-consuming because it was associated with the deeper processing of the sentences, which should be supported by cognitive resources.

7.2.2 *Must/or* Sentences Granting Strong Permission

Based on the overall derivation rates of the three types of inferences in the *must/or* version of the experiment, we could say that in general *must/or* sentences, such as (41), grant strong permission. More specifically, the set of deontically accessible worlds of (41) can only consist of a set of worlds in which the child only buys an orange and a set of worlds in which the child only buys a banana, and it cannot contain any world that does not belong to those two types of worlds.

(41) The child must buy an orange or a banana.



Notes
The orange circle denotes a set of worlds in which the child buys an orange.
The green circle denotes a set of worlds in which the child buys a banana.
The black circle denotes a set of worlds in which the child buys a pear.
The blue shadow denotes the set of deontically accessible worlds.

Similar as what I have done for *may/or* sentences, I also examined whether there is any individual difference in interpreting *must/or* sentences (see Table 7.2).

Table 7.2 Individual Difference in Interpreting *Must/or* Sentences

Group	Subgroup	Number of Participants
Low-FC Group	-	2
High-FC Group	Absolute Strong Permssion Group (ASP Group)	13
	Near-Absolute Strong Permission Group (NASP Group)	9
	Neither Weak Nor Strong Permission Group (NWNSP Group)	1

Note: *FC* is the abbreviation for *free choice inferences*.

I categorized 2 participants into the Low-FC Group because their derivation rates of free choice inferences were below 17%. I categorized the rest of participants (i.e., 23 participants) into the High-FC Group. In the High-FC Group, 6 participants derived free choice inferences 83% to 92% of the times, while 17 participants derived free choice for all occurrences of *must/or* sentences. I further divided the High-FC group into three subgroups. All 13 participants in the Absolute Strong Permission Group derived both exhaustivity inferences and exclusive *or* inferences for all occurrences of *must/or* sentences. All 9 participants in the

Near-Absolute Strong Permission Group had 83%-92% derivation rates of both exhaustivity inferences and exclusive *or* inferences. In addition, I found one participant who had a very high derivation rate of exhaustivity inferences (i.e., 92%), but a very low derivation rate of exclusive *or* inferences (i.e., 17%), and I categorized him/her into the Neither Weak Nor Strong Permission Group. From the examination of individual difference, we can conclude that 88% (i.e., 22/25) of the participants by default interpreted *must/or* sentences as expressions granting strong permission.

Now we have a clear idea about the similarity in the derivation rates of the three types of inferences associated with *must/or* sentences, i.e., all three types of inferences were derived very frequently with the overall derivation rates no lower than 90%. Then how about their processing time-courses? By examining the reaction time data, I found that the processing time of all three types of inferences was very similar to each other, and in addition, it was also very similar to that of logical interpretations. This indicates that the derivation of all three types of inferences was not time-consuming. Now the question is that based on the derivation rates and processing time-courses, could we possibly say that all three types of inferences were derived as parts of logical meanings of *must/or* sentences?

To begin with, please first notice that I used the same design, or more accurately, the same items, to examine inferences drawn from *may/or* sentences and *must/or* sentences. Based on this, if exclusive *or* inferences and exhaustivity inferences drawn from *may/or* sentences were derived as implicatures, then we could reasonably say that implicature computation under my paradigm was optional and time-consuming. Since all three types of inferences drawn from *must/or* sentences were derived very frequently and without a delay in processing time, we could further conclude that all three types of inferences behaved very differently from implicatures, but they behaved similarly as logical interpretations. So how should we explain the similarities between the three types of inferences drawn from *must/or* sentences and logical interpretations?

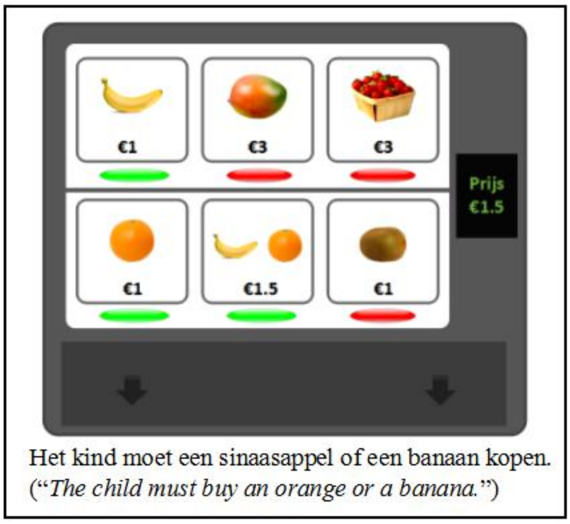
It is easy to understand why exhaustivity inferences drawn from *must/or* sentences are parts of logical meanings of *must/or* sentences. We could explain it as that disjunction in *must/or* sentences introduces a closed set of alternatives (Alonso-Ovalle, 2006; Zimmermann, 2000, etc). Alternatively, we could also attribute it to the semantics of deontic necessity modal which stipulates that the deontic domain should be entailed by the domain of disjunction, which is sets of alternatives (Simons, 2004). It is also comparatively easy to understand why free choice inferences drawn from *must/or* sentences behaved like logical meanings, because based on the alternative semantics of *must/or* sentences (Geurts, 2005; Simons, 2004), free choice inferences could just be derived as the results of the computation of truth conditions. I think that free choice inferences drawn from *must/or* sentences might much less likely be a special type of scalar implicatures that are derived costlessly and by default, because if we explain free choice inferences in this way, it could be very hard for us to explain the processing patterns of exclusive *or* inferences and exhaustivity inferences drawn from *may/or* sentences (see Section 7.2.1). Now the remaining question is that how could we explain the frequent and not-delayed derivation of exclusive *or* inferences of *must/or* sentences? Since exclusive *or* inferences are primarily associated with the occurrence of disjunctive coordinator and they are irrelevant to other meaning components of the sentences, we would expect exclusive *or* inferences drawn from *must/or* sentences to behave very similarly as those drawn from *may/or* sentences, and both types of exclusive *or* inferences should behave similarly as scalar implicatures. However, under the current paradigm, I observed that exclusive *or* inferences drawn from *may/or* sentences behaved like scalar implicatures, but exclusive *or* inferences drawn from *must/or* sentences behaved like logical interpretations. This result is very unexpected, and no theoretical study I reviewed predicts this. Here, I prefer to attribute this unexpected result to one of the potential problems in the paradigm, which is further discussed in Section 7.3.

7.3 Potential Problems in Experimental Paradigm

In this part, I focus my discussions on three crucial problems in the experimental paradigm. The problems I found may shed light on three problematic experimental results.

The first problem I want to discuss concerns why I observed a 94% derivation rate of exclusive *or* inferences in the *must/or* version and why the derivation of exclusive *or* inferences in the *must/or* version was not associated with processing cost. The results of exclusive *or* inferences in the *must/or* version were in contradictory with the predictions of all theoretical studies I reviewed. Let's first recall the type of items created for the exclusive *or* condition.

Figure 7.2 Item in the Exclusive *or* Condition in the *Must/or* Version



Based on *scalar implicature* accounts (Fox, 2007; Alonso-Ovalle, 2006), the logical meaning of the *must/or* sentence in Figure 7.2 is that the child must buy at least one fruit among an orange and a banana. This meaning is compatible with the situation in which the child is allowed to an orange and a banana. When implicature computation is activated, the primary implicature of the sentence, which implies that the child is allowed to buy an orange and a banana (see Section 2.2), can be derived. Till here, we can clearly see that both the logical interpretation and the primary implicature of the *must/or* sentence given in Figure 7.2 are compatible with the picture which conveys the information that to buy a banana is permissible, to buy an orange is permissible, and to buy a banana and an orange is also permissible. So based on scalar implicature accounts, we would expect participants to always judge the sentence in Figure 7.2 as the correct description of the situation depicted by the picture, and we would expect the derivation rate of exclusive *or* inferences to be near 0%. Semantic accounts (Simons, 2004; Geurts, 2005) analyze the exclusive *or* constraint as a pragmatic constraint, which should be applied to disjunction to regulate the overlapping between individual disjuncts. Based on this, the exclusive *or* inference of the *must/or* sentence, which implies the child must not buy an orange and a banana, should be optionally derived as a type of conversational implicature. Based on these accounts, we would expect a moderate derivation rate of exclusive *or* inferences, and we would expect the derivation of exclusive *or* inferences to be associated with longer processing time. However, contradictory to predictions of both types of accounts, I observed the frequent and not-delayed derivation of exclusive *or* inferences of *must/or* sentences.

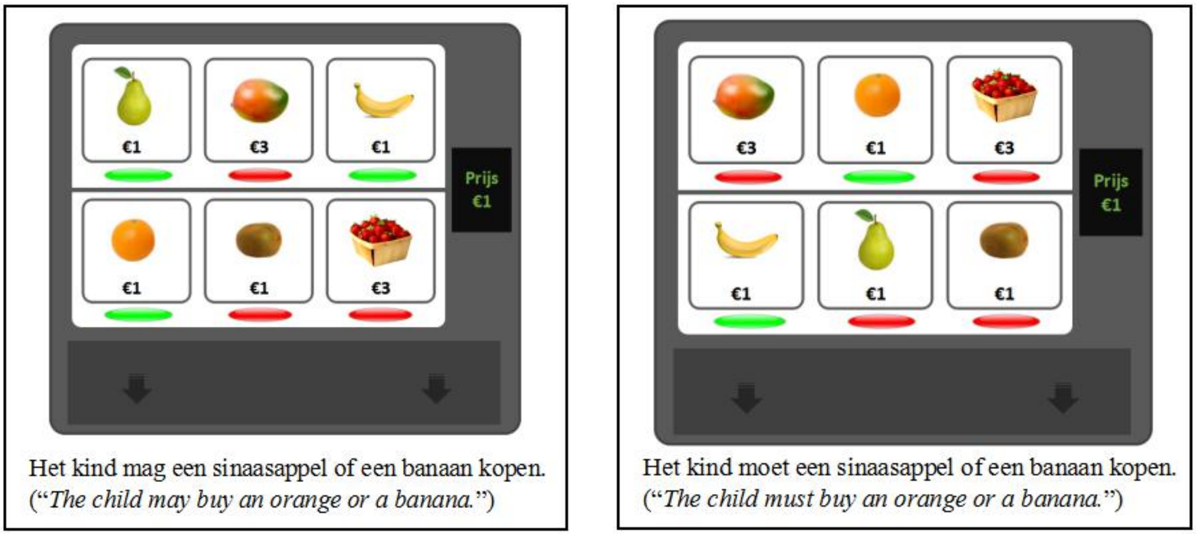
In order to explain the abnormality in the results, I looked into the design of the *must/or* version, and I found a potential problem in the cover story. The cover story of the *must/or* version is only different from that of the *may/or* version in one aspect: in the cover story of the *must/or* version, I added one additional piece of information to satisfy the meaning of *moeten* ("must"). The additional piece of information is as follows:

(42) Het kind moet met de geldprijs <u>iets</u> van de speelautomaat kopen, omdat de machine anders het volgende spel niet kan laden.
"*The child must buy <u>something</u> from the slot machine with the cash price, otherwise the machine can not load the next game.*"

The potential problem is that I used the Dutch indefinite pronoun *iets* in the cover story, which means "something" in English. Or more accurately, in dictionary, *iets* means a certain undetermined or unspecified thing. With regard to how participants might interpret *iets*, there are two possibilities. First, there might be a group of participants who were very sensitive to informativeness, so they might think that *iets* should by default indicate one and only one unspecified object and it cannot represent more than one object. Second, there might also a group of participants who think that logically, *iets* means at least one unspecified object. And if they computed scalar implicatures and strengthened the logical meaning of *iets*, *iets* could then means one but not more than one unspecified object. Based on these, we could reasonably say that it is of a fairly high likelihood that participants interpreted the information I added for the *must/or* version as that the child must buy one and only one object from the slot machine with the cash price. If it is the case, then participants' interpretation of *must/or* sentences throughout the entire experiment might always be accompanied by the presupposition that there is no permission for the child to buy more than one object from the lottery machine, and this presupposition might have facilitated the derivation of exclusive *or* inferences to a large extent. Based on the above arguments, the processing pattern of exclusive *or* inferences drawn from *must/or* sentences could be well explained.

The second problem I want to discuss concerns why the reaction times associated with *true* responses in the exhaustivity condition and the exclusive *or* condition in the *may/or* version of the experiment were significantly longer than those in the true control condition.

Figure 7.3 Items in the Exhaustivity Condition and the True Control Condition in the *May/or* version



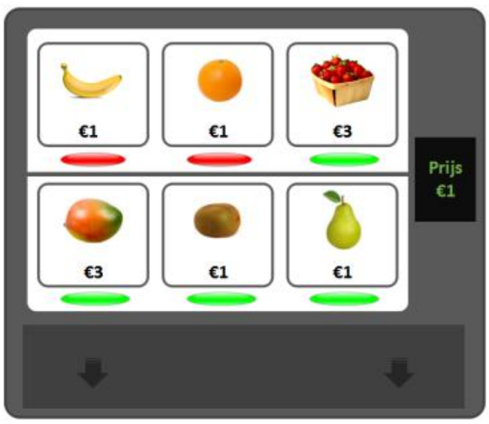
(a) exhaustivity condition (b) true control condition

(a) in Figure 7.3 is one of the items used in the exhaustivity condition in the *may/or* version and (b) in Figure 7.3 is one of the items used in the true control condition in the *may/or* version. Logically, as long as the child is allowed to buy at least one of the fruit among an orange and a banana, the *may/or* sentence given in Figure 7.3 is true. So the logical meaning of the *may/or* sentence is compatible with the pictures in both (a) and (b), because in both pictures the child is allowed to buy an orange and he/she is also allowed to buy a banana. Based on this, *true* responses in both the exhaustivity condition and the true control condition were only involved with the computation of the logical interpretations of *may/or* sentences. Theoretically, if *true* responses in the exhaustivity condition and the true control condition were associated with the computation of the same type of logical interpretations, we would expect the reaction times associated with *true* responses in the two conditions to be very similar as each other. However, I actually observed that the reaction time associated with *true* responses in the exhaustivity condition was significantly longer than that in the true control condition. So how could we possibly explain this difference in reaction times?

I think the longer reaction time associated *true* responses in the exhaustivity condition can be attributed to the possibility that it took participants longer time to process the pictures in this condition. Before getting into details, let's first recall how I measured the reaction time in this study. As is mentioned in Section 5.1, I recorded the time period from the occurrence of the last chuck of the target sentence to the pressing of the left/right button on the button box as the reaction time. The reaction time should include the amount of time participants needed to interpret the target sentence and the amount of time participants needed to interpret the picture combined with the sentence. Please notice that I do not think that the processing of the picture might take place before of the processing of the sentence because I added six types of filler items (see Section 5.2.3 and Appendix) to prevent participants to do so. More specifically, although pictures used in testing items and filler items were very similar to each other, only pictures in testing items should be interpreted as situations which depict what a child is allowed to buy, while pictures in filler items should be interpreted in completely different ways. For example, For some of the pictures in filler items, participants only needed to pay attention to the price tags beneath the objects; and for some of the pictures in filler items, participants only needed to pay attention to the right/green lights beneath the objects. Since filler items and testing items were pseudo-randomized and since pictures combined with different types of sentences should be interpreted in different ways, the most reasonable way to do the picture-sentence task in this experiment is to read the sentence first and then interpret the picture. Therefore, the reaction time not only reflects how participants processed the sentences, but also reflects how they processed the pictures. Now let's get back to Figure 7.3. Participants might need a longer processing time to interpret the picture in (a) than the picture in (b) because the picture in (a) is more complicated than the picture in (b). When interpreting the picture in (a), participants needed to pay attention to one more fruit (i.e., the pear in the picture) and they also needed to compare the price tag beneath the additional fruit with the cash prize presented on the screen. All these additional checking and comparisons took time. If the processing time of the picture in (a) was longer than that of the picture in (b), then the reaction time of the item in (a) should also be longer than that of the item in (b). Therefore, the longer reaction time associated with *true* responses in the exhaustivity condition could be attributed to the complexity of the pictures used in this condition. The same answer can also be used to explain the delayed *true* responses in the exclusive *or* condition. Since the degree of complexity of the pictures might also influence the reaction times, when I reported the reaction time results in Section 6.2, I not only made between-condition comparisons, but also made within-condition comparisons.

The last problem I want to discuss concerns why some participants had high error rates in the false control condition in the *may/or* version. Let's first recall the type of the items used in this condition.

Figure 7.4 Item in the False Control Condition in the *May/or* Version



Het kind moet een sinaasappel of een banaan kopen.
("*The child must buy an orange or a banana.*")

Although the cover story explicitly conveyed the information that the cash prize a child has, the price of the objects and the availability of the objects are all associated with permission granting, some participants might still constantly relate the availability of the objects to the possibility of buying them. More specifically, they might constantly think that the red lights beneath the banana and the orange in Figure 7.4 only indicate that there exists no banana and orange in the lottery machine, so it is not possible to buy them. They might further reason that whether it is possible to buy an object has nothing to do with whether it is permissible to buy it. If it is the case, then they would constantly interpret the picture in Figure 7.4 as that since enough cash prize has been award to the child for buying an orange or a banana, it is just impossible but not impermissible for him/her to buy a banana or an orange. As a result, they would judge the sentence in Figure 7.4 as the correct description of the picture. I found 7 participants who had above 40% error rates in the false control condition in the *may/or* version, and it is very likely that they made mistakes because they did not notice that the availability of the objects also determines what a child is allowed to buy. Since they might have wrong understandings about the type of the task I asked them to do, I excluded all their data from analysis.

7.4 Conclusion and Implicatures for Theoretical Studies

In the *may/or* version of the experiment, I found that a majority of the participants (56%) always interpreted *may/or* sentences as expressions granting weak permission. I observed that in the processing of *may/or* sentences, free choice inferences were derived very frequently and without a delay in processing time, while exhaustivity inferences and exclusive *or* inferences were optionally derived and the derivation of them was accompanied by an increase of processing time. Based on the discussions in Section 7.2, I argue that exhaustivity inferences and exclusive *or* inferences drawn from *may/or* sentences could be implicatures, while free choice inferences could very likely be the default logical interpretations of *may/or* sentences.

In the *must/or* version of the experiment, I found that a large majority of the participants (88%) always interpreted *must/or* sentences as expressions granting strong permission. I observed that in the processing of *must/or* sentences, free choice inferences, exhaustivity inferences and exclusive *or* inferences were all derived very frequently and without a delay in processing time. I argue that exhaustivity inferences and free choice inferences could be parts of default logical interpretations of *must/or* sentences. However, I would not make any claim about the exclusive *or* inferences drawn from *must/or* sentences due to the potential problem in the experimental paradigm.

The findings of the experiment may shed some light on the theoretical field. Now let's get back to the hypotheses in (36) in Section 4 to see to what extent different types of theories may explain the experimental results.

Scalar implicature accounts (Fox, 2007; Alonso-Ovalle, 2006) cannot explain two pieces of results in the experiment. First, they cannot explain why exhaustivity inferences were not drawn from *may/or* sentences by default. The exhaustification operator proposed by Fox (2007) and the existential closure operator proposed by Alonso-Ovalle (2006) can only operate over a closed set of alternatives introduced by disjunction. Based on this, exhaustivity inferences should always be derived, or the implicature computation cannot be activated. Second, it could be very hard for scalar implicature accounts to systematically explain the frequent and not-delayed derivation of free choice inferences and the optional and delayed derivation of exclusive *or* inferences and exhaustivity inferences drawn from *may/or* sentences. Based on these, I think that free choice inferences might not be scalar implicatures.

Similar as *scalar implicature* accounts, the conjunctive analysis of disjunction (Geurts, 2005) also has problems in explaining why exhaustivity inferences were only optionally derived for *may/or* sentences, because it also proposes that disjunction introduces a closed set of alternative propositions. One possible way to modify this analysis is to assume that disjunction introduces an open set of alternatives under deontic possibility modals, but it introduces a closed set of alternatives under deontic necessity modals. However, I do not think it is wise to make such an expression-specific assumption. Theoretically, it could be very hard to explain why disjunction should behave very differently under the same type of modals, i.e, deontic modals.

Finally, it seems that the experimental data can be well explained by sets account (Simons, 2004), which proposes that the modals in *may/or* sentences and *must/or* sentences operate over sets of alternatives introduced by disjunction. Simons's (2004) account can successfully explain the absence of the exhaustivity constraint in the semantics of *may/or* sentences and the presence of the exhaustivity constraint in the semantics of *must/or* sentences, and it also predicts the default derivation of free choice inferences and the optional derivation of exclusive *or* inferences. However, we do need to notice that similar as most of the semantic analyses of *modal/or* sentences (e.g. Zimmermann, 2000; Geurts, 2005; etc.), Simons's (2004) account is not fully developed and it is still problematic in explaining some of the phenomena associated with free choice inferences. One of the most crucial problems of it is that it cannot explain the cancellation of free choice inferences in downward entailing environments.

Additionally, I also want to make some brief remarks about the theoretical studies which adopt resource-sensitive reasoning to analyze *may/or* sentences (e.g. Barker, 2010). Barker (2010) abandons the standard modal logic but adopts the linear logic to analyze *may/or* sentences. He regards permission as limited resource, and he analyzes *may/or* sentences as expressions granting strong permission. For *may/or* sentences such as *the child may buy an orange or a banana*, his reasoning is that normally the speaker does not expect the child to use the limited resource to buy a fruit that is not explicitly mentioned; and normally the speaker does not grant enough resources for the child to buy both types of fruits. Apparently, the analysis of *may/or* sentences based on the resource sensitivity reasoning does not fit the experimental data. The strong permission defined by the resource sensitivity reasoning is more close to the permission granted by *must/or* sentences. Thus, I think that compared with the novel logic which is adopted to analyze disjunction under deontic modals, the standard modal logic might fit the empirical data better.

Appendix

Here is a quick guidance of Appendix. In A.1, I explain Sauerland's (2004) Neo-Gricean account. In A.2, I explain Hamblin's (1973) rules and Simons's (2004) independent composition. In A.3, I present the cover story used in the experiment. In A.4, I present all items I used in the practice section of the experiment. In A.5, I present examples of the testing items (including control items and target items) I used in the experiment. In A.6, I present examples of filler items.

A.1 Sauerland's (2004) Neo-Gricean Account

Sauerland's (2004) Neo-Cricean account is a modified version of the classical Gricean reasoning proposed by Grice (1975). It enriches the Gricean account mainly in two aspects. First, it introduces a new algorithm to compute alternatives of disjunction. Second, it modifies the maxim of quantity by adding the idea of the "opinionated speaker".

Sauerland's algorithm for alternatives of disjunction is as follows:

(1) Alt ($[[A \vee B]]$) = $\{A\ \boldsymbol{L}\ B, A\ \boldsymbol{R}\ B, A \wedge B, A \vee B\} = \{A, B, A \wedge B, A \vee B\}$

Notes: $A\ \boldsymbol{L}\ B = A$; $A\ \boldsymbol{R}\ B = B$

(The connective ***L*** takes the entire disjunction and returns the left-hand side disjunct.

The connective ***R*** takes the entire disjunction and returns the right-hand side disjunct.)

The "Opinionated speaker" stipulates that the speaker in a conversation is by default opinionated towards the stronger alternatives of an uttered proposition. The maxim of quantity modified by the "opinionated speaker" is defined as follows:

(2) Assume that p is a proposition uttered by the speaker. For $\forall$ p' $\in$ Alt (p), if p' is logically stronger/more informative than p, the speaker by default believes that p' is false as long as it is not contradictory with the speaker's other beliefs.

Sauerland's Neo-Gricean account successfully predicts the ignorance inferences and scalar implicatures drawn from disjunction. Below I provide an example of Sauerland's reasoning.

(3) a. John had a sandwich or an apple pie.

b. Alt (3a)=$\{s\ \boldsymbol{L}\ a, s\ \boldsymbol{R}\ a, s \wedge a, s \vee a\}$[47] $= \{s, a, s \wedge a, s \vee a\}$

c. Bs ($s \vee a$) (the maxim of quality)

d. Primary Implicatures (PIs): (the maxim of quantity)

$\neg$ Bs (s) & $\neg$ Bs (a) & $\neg$ Bs ($s \wedge a$)

(Note: PIs = $\{\neg$ Bs (p'): $\forall$ p' $\in$ Alt(p) and p' is stronger than p$\}$[48])

e. Secondary Implicatures (SIs): (opinionated speaker)

$\neg$ ($s \wedge a$) is not contradictory with (1c) and PIs in (1d),

therefore $\neg$ Bs ($s \wedge a$) is strengthened to Bs ($\neg$ ($s \wedge a$)).

(Note: SIs = {Bs ($\neg$ p'): $\forall$ p' $\in$ Alt(p), p' is stronger than p, and Bs ($\neg$ p') $\wedge$ PIs $\wedge$ Bs (p) is not

[47] Notes on abbreviations: *s* represents *a sandwich*. *a* represents *an apple pie*.

[48] An explanation of PIs: for each alternative proposition (p') that is stronger than the proposition (p) uttered by the speaker, we derive the inference that it is not the case that the speaker believes p' is true.

contradictory}[49])

f. strengthened meaning: $Bs\ (s \vee a)\ \&\ \neg Bs\ (s)\ \&\ \neg Bs\ (a)\ \&\ Bs\ (\neg (s \wedge a))$

(3f) is the strengthened meaning of (3a). It entails two ignorance inferences which indicate that the speaker is not sure whether John had a sandwich and that the speaker is also not sure whether John had an apple pie. It also entails a scalar implicature which indicates that the speaker believes that John does not had both a sandwich and an apple pie.

A.2 Hamblin's (1973) Rules and Simons's (2004) Independent Composition

Hamblin (1973) and Simons (2004) propose very similar alternative semantics for disjunction. In this study, I makes no distinction between Hamblin's (1973) rules and Simons's (2004) semantic composition. I roughly regard them as the same type of the non-standard analysis for disjunction.

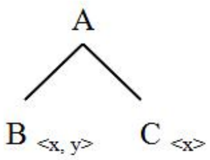
Hamblin (1973) and Simons (2004) propose that the semantic composition of a disjunction should be a set whose members are the standard denotations of all its individual disjuncts. Furthermore, all individual disjunctions in a disjunction should be of the same type.

(4) $[A_1 \text{ or } A_2 \text{ or ... or } A_n] = \{[[A_1]], [[A_2]], ..., [[A_n]]\}$

(Note: $A_1, A_2 ... A_n$ are of the same type.)

Since the semantics of a disjunction is a set of denotations, a new rule is needed to stipulate the semantic composition of sentences containing disjunction. Therefore, Hamblin proposes a set of rules, which is similar as Simons' independent composition.

(5)



Rule 1: Let C be a set of denotations, then $[[A]] = \{a: \exists c \in C\ \&\ a = [[B]](c)\}$

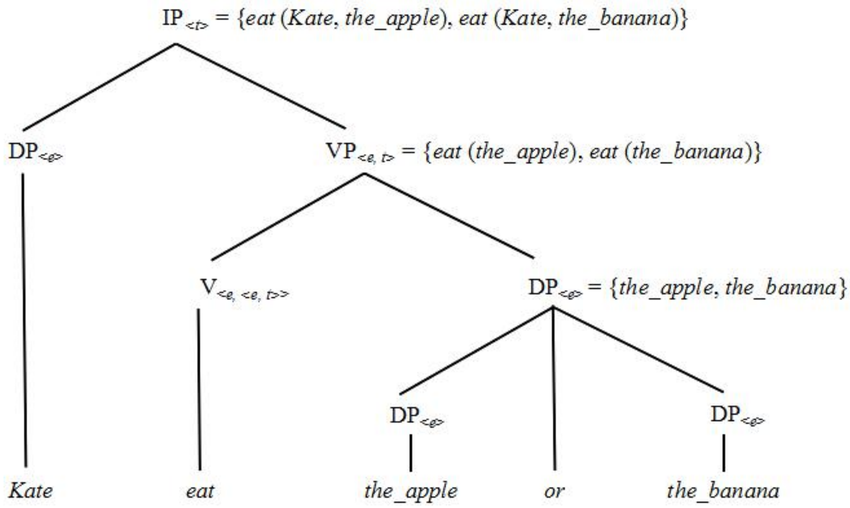
Rule 2: Let B be a set of denotations, then $[[A]] = \{a: \exists b \in B\ \&\ a = [[C]](b)\}$

Rule 3: Let each of B and C be a set of denotations, then $[[A]] = \{a: \exists b \in B\ \&\ \exists c \in C\ \&\ a = c(b)\}$

According to Hamblin's rules, (6) is expected to go through following semantic composition:

[49] An explanation of SIs: for each alternative proposition (p') that is stronger than the proposition (p) uttered by the speaker, the speaker believes p' is false if this belief is not contradictory with all primary implicatures and the speaker's belief on p.

(6) Kate ate the apple or the banana.



This is to say that under Hamblin and Simons' alternative semantics, the denotation of (6) should be a set of propositions: {*eat* (*Kate*, *the_apple*), *eat* (*Kate*, *the_banana*)}.

A.3 Cover Story

Note: The piece of information which was only present in the *must/or* version of the experiment is underlined.

Dutch Version

In dit experiment geeft elke afbeelding een speelautomaat voor kinderen weer. Nadat een kind een spelletje heeft gewonnen, toont het kleine scherm aan de rechterkant van de machine het totale bedrag van de geldprijs die het kind is toegekend. Op het centrale scherm van de machine worden zes verschillende items weergegeven. De prijs en de beschikbaarheid van de artikelen worden weergegeven onder elk van de artikelen. De prijs wordt aangegeven in euro's. Een groen licht betekent dat het artikel beschikbaar is en een rood licht betekent dat het artikel niet beschikbaar is. Het kind moet met de geldprijs iets van de speelautomaat kopen, omdat de machine anders het volgende spel niet kan laden. De prijs van de artikelen, de beschikbaarheid ervan en het bedrag van de geldprijs die het kind is toegekend, bepalen welke artikelen het kind mag kopen van de speelautomaat.

English Translation

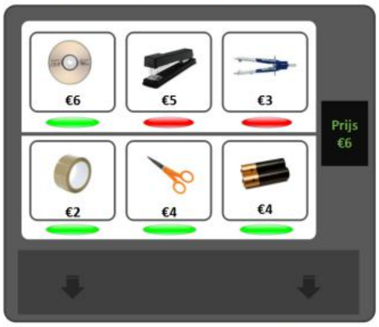
"*Every picture in this experiment will show a lottery machine for children. After a child wins a lottery game, the small screen on the right hand side of the machine will display the total amount of the cash prize the child has been awarded. The central screen of the machine will display six different items. The price and availability of the items are displayed below each one of the items. The price is indicated in Euros. A green light indicates an available item and a red light indicates that the item is not available for purchase. The child has to make a purchase on the lottery machine with the cash prize he or she has been awarded, otherwise*

<u>the machine will be unable to load the next lottery game.</u> The price of the items and their availability as well as the amount of prize the child has been awarded all determine what items the child is allowed to buy from the lottery machine."

A.4 Practice Items

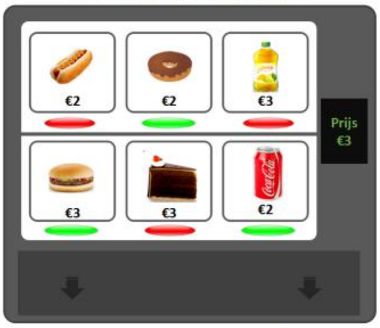
Practice Items in the *May/or* Version

Het kind mag een paar batterijen kopen.
"The child may buy a pair of batteries."



Correct response: T

De hamburger is beschikbaar.
"The hamburger is available."

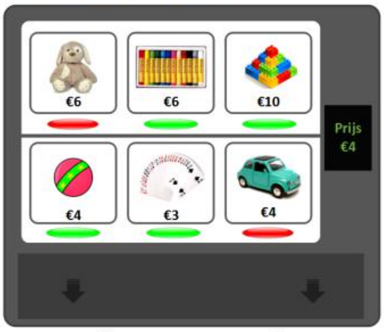


Correct response: T

Het kind mag een pak melk kopen.
"The child may buy a box of milk."

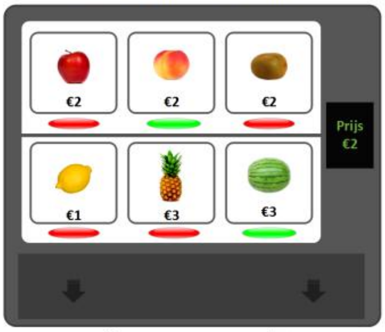
Correct response: F

Het kind mag een speelgoedauto kopen.
"The child may buy a toy car."



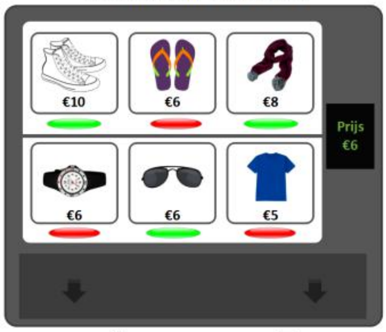
Correct response: F

De watermeloen is beschikbaar.
"The watermelon is available."



Correct response: T

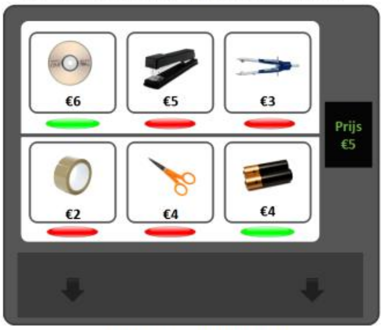
Het kind mag een sjaal kopen.
"The child may buy a scarf."



Correct response: F

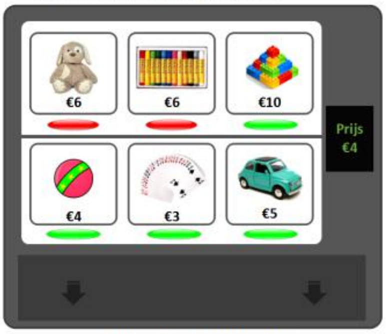
Practice Items in the *Must/or* version

Het kind moet een paar batterijen kopen.
"The child must buy a pair of batteries."



Correct response: T

Het kind mag een speelgoedauto kopen.
"The child may buy a toy car."

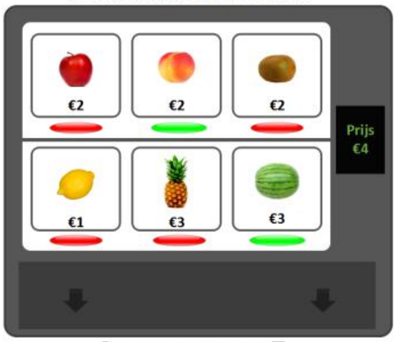


Correct response: F

Het kind moet een sjaal kopen.
"The child must buy a scarf."

Correct response: F

De watermeloen is beschikbaar.
“The watermelon is available.”

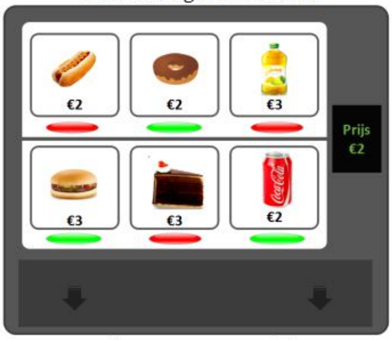


Correct response: T

Het kind mag een pak melk kopen.
“The child is may buy a box of milk.”

Correct response: F

De hamburger is beschikbaar.
“The hamburger is available.”



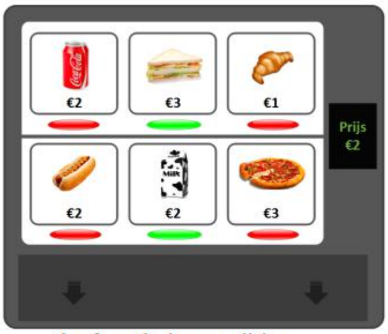
Correct response: T

A.5 Examples of Testing Items

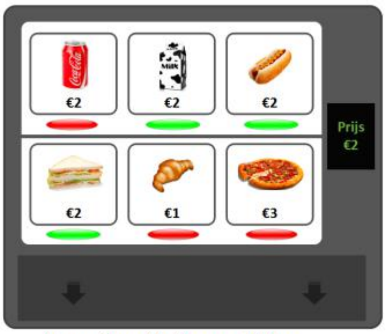
Example of Target Items in the *May/or* Version and the *Must/or* Version

The statement in *may/or* version
Het kind mag een broodje of een pak melk kopen.
“The child may buy a sandwich or a box of milk.”

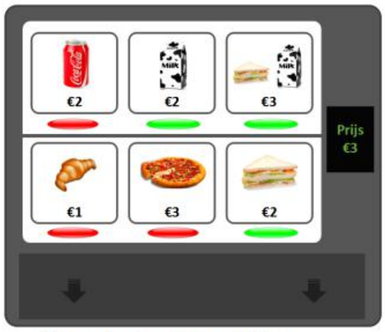
The statement in *must/or* version
Het kind moet een broodje of een pak melk kopen.
“The child must buy a sandwich or a box of milk.”



the free choice condition
Correct response: T/F



the exhaustivity condition
Correct response: T/F

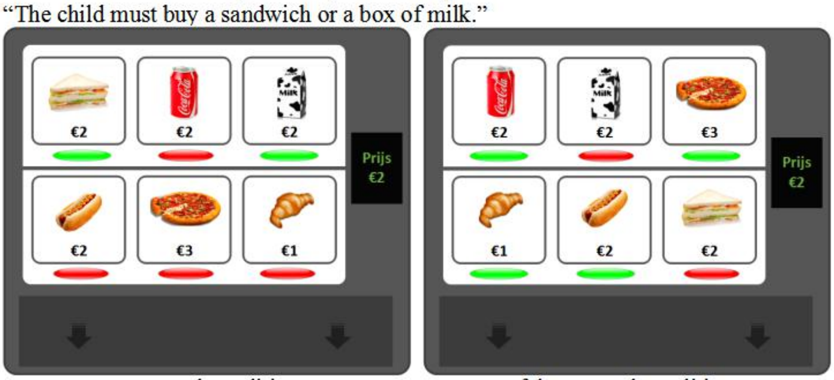


the exclusive *or* condition
Correct response: T/F

Examples of Control Items in the *May/or* Version and the *Must/or* Version

The statement in *may/or* version
Het kind mag een broodje of een pak melk kopen.
"The child may buy a sandwich or a box of milk."

The statement in *must/or* version
Het kind moet een broodje of een pak melk kopen.
"The child must buy a sandwich or a box of milk."

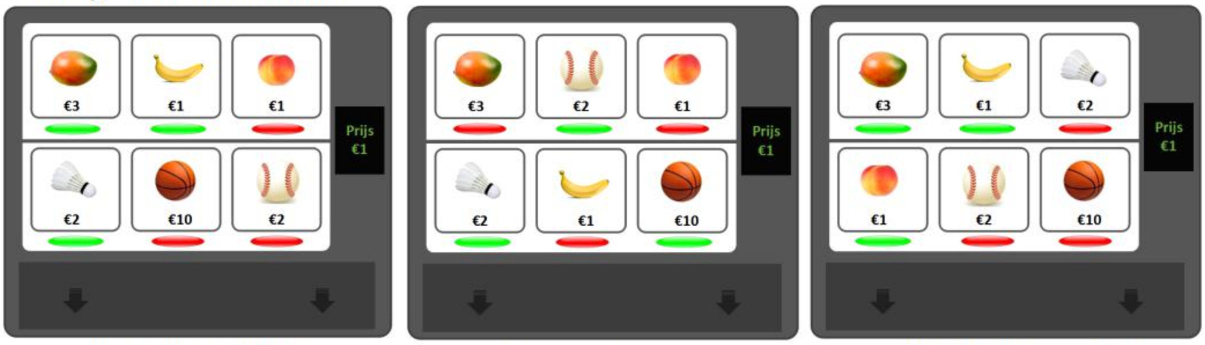


true control condition
Correct response: T

false control condition
Correct response: F

A.6 Examples of Filler Items

Statement
Sommige fruitsoorten zijn beschikbaar.
"Some types of fruits are available."

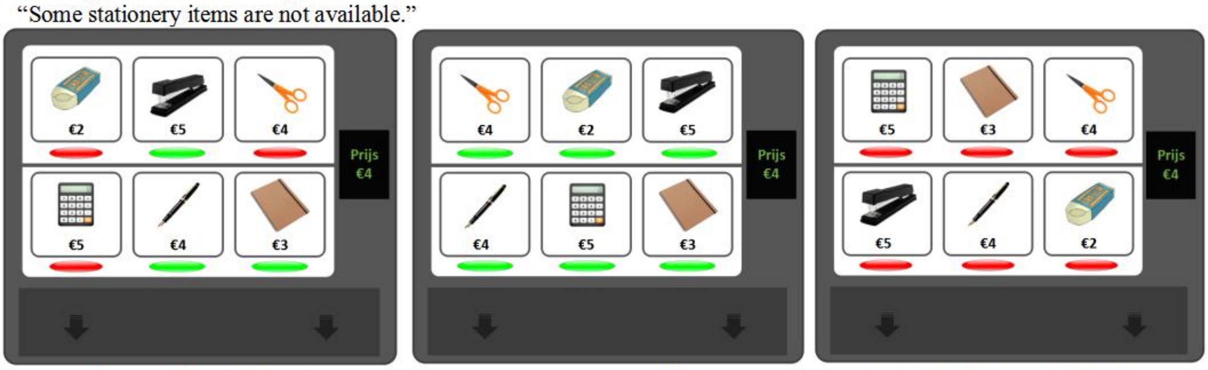


true control condition
Correct response: T

false control condition
Correct response: F

scalar implicature condition
Correct response: T/F

Statement
Sommige kantoorartikelen zijn niet beschikbaar.
"Some stationery items are not available."



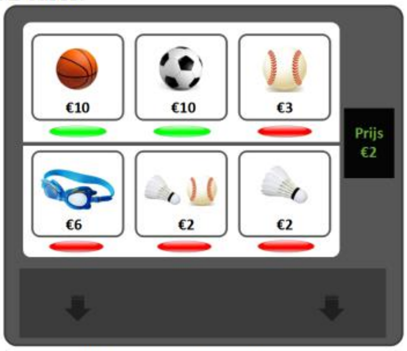
true control condition
Correct response: T

false control condition
Correct response: F

scalar implicature condition
Correct response: T/F

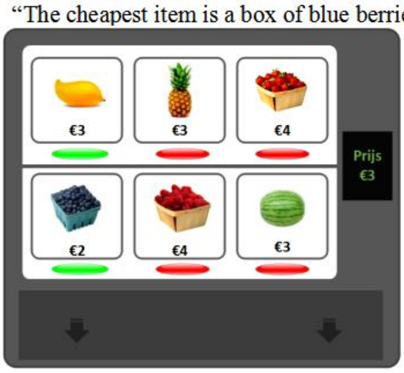
Statement
Zowel een honkbal als een shuttle kost 2 euro.
"Both a baseball and a badminton ball cost 2 euros."

true control condition
Correct response: T

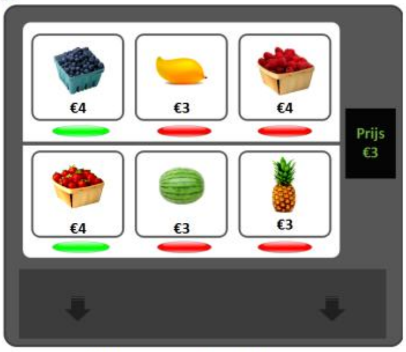


false control condition
Correct response: F

Statement
Het goedkoopste artikel is een doosje blauwe bessen.
"The cheapest item is a box of blue berries."



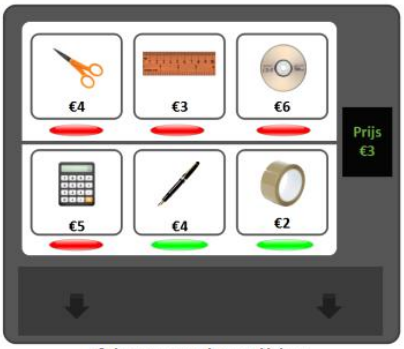
true control condition
Correct response: T



false control condition
Correct response: F

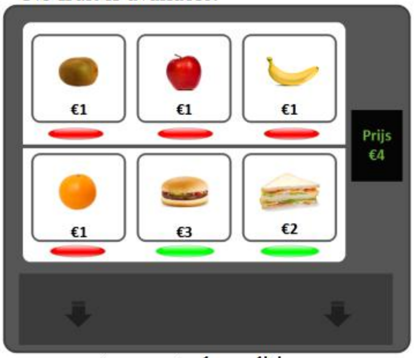
Statement
Het duurste artikel is een rekenmachine.
"The most expensive item is a calculator."

true control condition
Correct response: T

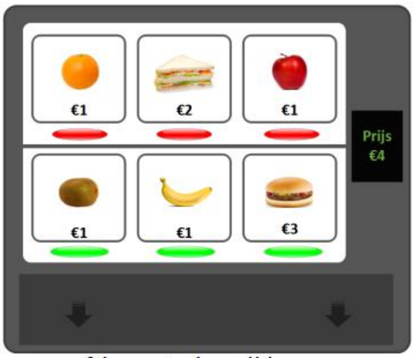


false control condition
Correct response: F

Statement
Geen enkel fruitsoort is beschikbaar.
"No fruit is available."



true control condition
Correct response: T



false control condition
Correct response: F

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