Resolving homonyms in context: understanding ambiguity for autism spectrum disorder

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Foreword

Making this thesis was, for me, a challenge and a joy. In the process I've overcome many obstacles, both in this research, as well as personal. I came to admire the way guided living is provided to adolescents with autism in The Netherlands, and learned much about the practical side, and research of autism. I've learned a huge amount on doing research and carrying out an experiment, which I see as great additions to my academic and educational career. I am proud of what I could accomplish in doing this research, and I am hopeful that I can interest anyone who reads this.

Before moving on to the contents of this thesis, I would like to thank my supervisors, Pashiera and Franc, for their support and guidance. I learned great deals, shared enthusiasm, and got inspired. Also, I would like to thank Stumass Eindhoven and Stumass Nijmegen, Capito Nijmegen and IVA Nijmegen, for their amazing support in helping out with the participants in the experiment. They not only provided contacts and resources, they welcomed me with great interest. Furthermore I would like to thank Guus for always being there and letting me discuss anything with her, including many things in this thesis that were challenging for me.

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Abstract

Current research suggests that individuals with autism spectrum disorder (ASD) have a lower strive for central coherence than Typically developing (TD) individuals. The particular issue of lexical ambiguity is outlined, as this seems to be a specific issue. A novel experiment is described, concerning disambiguation of homonyms in conditions without context, and with sentence context present. Participants were 30 individuals, 16 with high-functioning ASD, 14 typically developing controls, matched on age and gender. There was a significant interaction effect between group (ASD/TD) and condition (no context/context) for the performance of choosing subordinates. Implications of these findings are discussed; results of lower performance on disambiguation of homonyms in context can be used for diagnosis.

1. Introduction

"Daar is de bank waar we het over hadden!"

This Dutch sentence is very ambiguous, the Dutch word '*bank*' can have different meanings, like the English word '*bank*' can have as well. So in the Dutch language, this sentence (freely translated *"Over there, that's the bank we discussed!"*) can mean either *"Over there, that's the financial institution we discussed!"* or *"Over there, that's the bench we discussed!"*.
When communicating or reading, using language in general, we come across many ambiguities. For successful language comprehension we not only use the understanding of words in isolation, but also the ability to integrate different kinds of context to disambiguate the sense of a word, and to build a coherent mental representation of understanding (Bishop, 2000). This context can be the environment, relating words or sentences (discourse context), on-going syntactic analysis (Tyler, L. K., & Marslen-Wilson, 1981), or multiple other instances. With such a sentence as the above, often the surrounding context will help in the process of word sense disambiguation (WSD) (Kwong, 2008; Simpson & Gernsbacher, 1994) , determining the meaning of an ambiguous word.

If one focuses on lexical ambiguity, one can expect that there is a difference in understanding, or disambiguating, the sense of a word with multiple meanings, when positioned in a sentence that provides little to no context for the word, as opposed to the ambiguous word being placed in a context that gives associated words or sentences, that are directly related to *one* specific meaning of the word.

This thesis will look into that expected shift in distribution of meanings. A shift is expected from a chance or bias related distribution (that corresponds to the distribution when asking for word meaning of a word in absence of any preceding discourse context), to a distribution with a strong preference directing to *one* meaning of a word, when presented in directly relating context. (for example; expecting 50-50 distribution among an ambiguous word without preceding context, that would shift to a 90-10 distribution when accompanying, directly associating, words are preceding, relating to a specific one of the meanings of a word)

More specifically, this thesis deals with the possible differences in shifts, when considering the reading of sentences with an ambiguous word by people diagnosed with Autism Spectrum Disorder (ASD), compared to how typically developing people handle these sentences. ASD is of interest here, because ambiguities in language make social communication harder. As explained in chapter 2, social communication is in some ways impaired for individuals with ASD. As is explained in more detail later on, people with autism experience difficulties with tasks of sentence comprehension and using context.

A possible outcome is that the expected described shift takes place for typically developing persons, but not so much for persons with ASD.

On top of the existing *theory* from psychology and psycholinguistics, and the *experiment* that looks into the hypothesis described above, this thesis will offer suggestions following from the results for *future research*.

The research questions that flow from the above, are stated here:

Main research question:
"Does contextual information resolve lexical ambiguity for individuals with autism spectrum disorder?"

The different sub-questions are:

1. *Is ambiguity a problem that is resolved within ASD, in the same way as it is for typical developing individuals?*
2. *Does the use of context resolve ambiguity for people with ASD, in a task for meaning of homonyms?*
3. *Can results from measurements form input for future Artificial Intelligence (AI) applications, to help individuals be diagnosed with ASD?*

These three questions will be discussed in the different chapters that follow. One deals with the theory (chapter 2.): the *Literature* that exists and what we can interpret from this, the following describes the *Experiment* (3.) that was carried out, of which the methods and results are outlined, and the last question deals with the possible Application of the results, which are included in the *Discussion* (4.).

2. Literature

2.1. Autism and social interaction

To understand the whole of this thesis, it is important to understand what autism is. In this paragraph I will briefly discuss how autism manifests itself and what kind of consequences this has for the social life of an individual.

2.1.1. History

In 1943 Leo Kanner published an article in which he discussed a developmental disorder that he called *autism*. He defined three patterns of symptoms, namely:

1. The inability to use language as a means of communication
2. The abnormal development of social interaction
3. The desire for uniformity, reflected in repeatedly performing rituals and obsessive interests (Kanner, 1943)

He also suggested that autistic children are very withdrawn, introverted and not in contact with reality. He stated that people with autism have difficulty with learning from experience and the adapting to unpredictable situations in social life.

Over the past decades much research involving autism has been carried out, and many of the symptoms, characterisations and diagnostics have been refined.
When referring to autism here, I will use the term for the whole range of disorders. Autism Spectrum Disorder, here often referred to as ASD, consisting of a spectrum of manifestations that can take place in multiple forms, and to different degrees (Jordan, 2001).

2.1.2. Characterisation

ASD can be seen as a developmental disability that is for life, and affects the communication of a patient and one's relations. Nowadays, the main characteristics of ASD are stated as (DSM-V 299.00, 2013):

1. impaired social communication,
   verbal as well as in non-verbal communication, including difficulties with facial expressions, gestures, eye-contact, understanding mental state of others etc. Maintaining relationships becomes a difficulty as well, partly because they have difficulty sharing interests. (Orsmond, G. I., Krauss, M. W., & Seltzer, 2004)
2. Restrictive interests and repetitive behaviours,
   Being overly dependent on routines, highly sensitive to changes herein or in the environment, or intensely focused on inappropriate items

This updated characterisation of impairments is somewhat different than in the DSM-IV (1994). The coverage stayed the same, but the sub-categorisation for different types of ASD such as Asperger and PDD-NOS was removed. Therefore, in this paper the terms *autism* and ASD are used alternately, and both referring to the complete diagnosis of ASD.
On average, more males are diagnosed with ASD than females (APA, 2013; Newschaffer et al., 2007) (This is a characteristic of ASD that is controlled for in the Experiment section).
The ability to lead an independent life is reduced and also for high-functioning individuals with autism, everyday social patterns and rules pose puzzles. Understanding humour, ambiguity, white lies, metaphors are among difficulties that people with ASD come across.

Patients of ASD in adulthood who can take care of themselves fully, and have a full-time job are rare. Often, they are dependent on family or authorities (Kidd, 2002). Early diagnosis is useful in order to allow a positive development on the long-term, but even with early intervention, people diagnosed with ASD need high levels of care and support throughout their life (Christensen, 2012). It is established that autism can occur at any point on the IQ scale (Baron-Cohen, 2004).
An example to illustrate impaired social communication is the lesser ability to use prosody (tone-of-voice). This is a non-verbal trait, used to give context, like gestures and facial expressions can do as well. People with high-functioning autism have difficulty using prosody to disambiguate syntax, in comparison to typically developing individuals, even when matched on chronological age, IQ, and receptive language. (Diehl, Bennetto, Watson, Gunlogson, & McDonough, 2008)

2.1.3. Prevalence

There are many studies reporting very different statistics on the prevalence rates. The numbers contain the whole range of autism spectrum disorders and range from 1 in 68 American children (Christensen, 2012) (1 in 42 boys, 1 in 189 girls) to 1 in 100 in Europe (both in 2012) (Charman, T. et al 2011; Elsabbagh et al., 2012; Kim, Y. S. et al 2011; Saemundsen, E. et al 2013). A global review found a median of 62 cases per 10000 people, ± 1 in 160, however there is a lack of evidence for low- and middle-income countries (Elsabbagh et al., 2012).
What is clearly visible, is that the diagnosis rate increased rapidly in the last decades, but it is not yet clear whether this is due to adjustments in diagnostic criteria, increase in prevalence, or because of more awareness of autism. Also likely, the increase can be a combination of these factors.

2.2. Explanations

2.2.1. Research and explanatory studies

As mentioned earlier, one of the key difficulties for people diagnosed with ASD, is interaction and communication. Research on the topic of social skills in interaction has been carried out, with respect to visual ambiguity (Ropar, Mitchell, & Ackroyd, 2003), prosody (tone-of-voice) processing (Diehl et al. 2008), and use of context (López & Leekam, 2003), amongst many other things.
Important to note is that in ASD, the processing of phonology, semantics and syntax seem to be intact according to what is expected of matching mental age (Bartolucci, G. et al. 1976; Frith, U., & Snowling, 1983; Tager-Flusberg, H. et al. 1990).

One of the main issues when considering cognitive skills that are used for social interaction seems to be use of context. Low-level visual processing (Happé, F. et al. 1996; M. A. O'Riordan et al. 2001; M. O'Riordan & Plaisted, 2001; Plaisted, K. et al. 1999; Ropar, D., & Mitchell, 1999), high-level visuo-spatial processing (Brian, J. A., & Bryson, 1996; Shah, A., & Frith, 1983, 1993), semantic memory (Tager-Flusberg, 1991) and sentence processing (Happé, 1997; Hermelin, B., & O'connor, 1967; Jolliffe & Baron-Cohen, 1999) have been researched regarding the use of context. Most of these studies involve the use of context, and conclude that striving for integration of information is impaired, many studies on ASD rely for this, on the theory of weak *central coherence* (CC), by Uta Frith (Frith, 1989).

Other explanatory theories of autism include the mindblindness theory / deficit in Theory of mind (ToM) (Baron-cohen, Leslie, & Frith, 1985), extreme-male brain theory as proposed by Baron-Cohen (1999), and the executive dysfunction (ED) theory (Ozonoff, S., Pennington, B. F., & Rogers, 1991). As Baron-Cohen notes extensively, all theories have pros and cons (Baron-Cohen, 2008).

2.2.2. Central Coherence

Frith stated that autism could be characterized by a specific unbalanced integration of information on different levels. This means that a typically developing person (TD) will have the tendency to pull together different pieces of information, to create a comprehensive meaning (Frith, U., & Happé, 1994). For example, Central Coherence means that with the hearing of a story, one will memorise the *global* content to form a correct whole. Many details are left out, because the remembering of these details would be detrimental to memorisation of the global picture. Frith assumed that people with autism show abnormalities with CC. She predicted that individuals with ASD would perform relatively well for tasks where attention to detail is more important than attention to the whole, and that they would have relatively bad performance on tasks where picking out the overall meaning was important.
The theory of weak central coherence in ASD is debated (Baron-Cohen, 2008; Jarrold & Russell, 1997), and corrected in 2006 (F. Happé & Frith, 2006). The most important change herein was the adjustment of the theory as an explanatory of ASD, to a aspect of cognition in ASD.

2.2.3. From Central Coherence onwards

Focusing on ambiguity and sentence comprehension, there are studies reporting results consistent with the theory of weak central coherence for individuals with ASD, and studies that seem to contradict the theory.

Difficulties in integrating different items and thus an impairment to form meaningful coherence (Baron-Cohen, S., Lombardo, M., & Tager-Flusberg, 2013), are demonstrated in a study by Diehl et al. (2008) where adolescents with high-functioning autism had difficulty using prosody to disambiguate syntax when compared to typically developing controls, matched on age, IQ, and receptive language (Diehl et al., 2008).
Also, studies by Happé, Joliffe & Baron-Cohen and Lopez & Leekham all showed that people with ASD were less likely to provide the correct pronunciation of homographs in context (A reoccurring example is *"Her dress/eye had a tear in it"*) (Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003).
Studies involving verbal tasks like inferencing (Jolliffe, T., & Baron-Cohen, 2000; Jolliffe & Baron-cohen, 2001; Ozonoff, S., & Miller, 1996) and resolving lexical and syntactical ambiguity (Jolliffe & Baron-cohen, 2001) showed similar results; individuals with autism showed impairment in striving for use of context to reach coherence. Individuals had verbal IQ results in normal range (Jolliffe & Baron-cohen, 2001). These studies were all involving verbal tasks, with auditory-presented stimuli.

However, Lopez & Leekham (2003) noted that the failure to use context properly seems to lie within tasks of verbal processing of ambiguity. Their experiments found that individuals with ASD were assisted using visual context information. Moreover, verbal processing tasks that did not involve ambiguity, but did ask for the use of context, also showed that the individuals with autism were facilitated by the provided context (López & Leekam, 2003).
They state: "*These findings demonstrate that children with autism do not have a general difficulty in connecting context information and item information as predicted by weak central coherence theory. Instead the results suggest that there is specific difficulty with complex verbal stimuli and in particular with using sentence context to disambiguate meaning."*
However, the study by Diehl et al. (2008) showed that not only sentence context, but also traits like tone-of-voice pose difficulties.

2.2.4. Conclusion

Assuming that the problem lies within the distinction of ambiguity, it is important to dive deeper in that area. It is important to focus on individuals that have high-functioning forms of ASD, and high verbal IQ, and not already have lower cognitive abilities (Vermeulen, 2011), to see if ambiguity really is a characterising, specific cognitive problem for autism, and not just a characteristic of learning disability, which can also be a cause of low cognitive ability.

As is clear, for high-functioning individuals with ASD, comprehension deficits may arise from a specific inefficiency in integrating linguistic, ambiguous information in context; an indicator for a lack in striving for central coherence. This thesis tries to add to the knowledge of lexical ambiguity being an indicator of weak central coherence, involving the comparisons of individuals with ASD and typically developing persons.

In these pages, I address the possible difficulties people with autism could have with disambiguation of *meaning*, when reading sentences containing *homonyms*. These are words with consistent spelling, but different meanings, whereas studies involving *homographs* address ambiguous *pronunciation*.
Also, earlier described past studies, concerning sentence comprehension and lexical ambiguity, used auditory presented stimuli, whereas reading is required in this experiment.

2.3. Language and ambiguity

Now we have established a clear understanding of what autism spectrum disorder encompasses, the skills for social interaction that are impaired and the specifics of weak central coherence. Particularly, we are interested in the weak coherence, combining context to a whole, in linguistic ambiguity, as this is an evident issue for ASD to be further explored.
In order to research linguistic ambiguity it is important to get a picture of how language, and ambiguity in language, works. I have summarised my findings of this in these paragraphs.

2.3.1. Language comprehension and the representation of word meaning

The comprehension of spoken or written language is a process that can be divided in steps, or levels of language analysis, see below figure:

Table 9-2 MILLER'S (1973) FIVE LEVELS OF LANGUAGE ANALYSIS

Level	Explanation
1. Phonology	Analysis of the sounds of language as they are articulated and comprehended in speech
2. Syntax	Analysis of word order and grammaticality (e.g., rules for forming past tense and plurals, rules for determining word ordering in phrases and sentences)
3. Lexical or semantic	Analysis of word meaning and the integration of word meanings within phrases and sentences
4. Conceptual	Analysis of phrase and sentence meaning with reference to knowledge in semantic memory
5. Belief	Analysis of sentence and discourse meaning with reference to one's own beliefs and one's beliefs about a speaker's intent and motivations

Figure 1: Five levels of language analysis (image taken from Ashcraft, 2006; Five levels of language analysis: Miller, 1973)

For this thesis, the lexical or semantic level is the most important: the analysis of the meaning of words. This is the level where meaning is obtained from memory. The memory of words is called the mental lexicon, a kind of dictionary in the brain that links words to their meanings.
One of the most important theories in psycholinguistics[1] is the network theory of the semantic memory. This model is based on two fundamental assumptions: an assumption about the structure of the semantic memory, and an assumption about the process of the retrieval of word meanings from the semantic memory (Ashcraft, 2006; Simpson & Gernsbacher, 1994)

Assumption about structure: a semantic network
The structure of the semantic memory is a network; therefore we speak of a semantic network. The idea is based on the concept of neural networks. The nodes in the network stand for concepts in the semantic memory (Ashcraft, 2006). Every word has a meaning and it is not unusual to interchange such a *word meaning* and *concept* within psycholinguistics (Gaskell, 2007, 152). The links that connect the nodes are directed associations between concepts. The collection of mutually linked nodes forms the network.

Assumption about process: spreading activation

[1] Psycholinguistics; the study of language as it is learned and used by humans (Ashcraft, 2006) In this field, language is primarily seen as human behaviour, as a mental process. Language is a form of cognition as well, and to understand language we use thought, memory and perception (Friedenberg & Silverman, 2006, 1-24)

The structure of the semantic memory as a network can not be considered separately from the process that occurs within this network: the retrieval of word meaning; or the recalling of the meaning of a word. Every node in the network has an activation value. When reading or hearing a word, the corresponding node gets active. With hearing or reading, the node generally gets so active that it reaches a threshold value, which we call the *firing* of a node.

An important aspect of the process of word meaning retrieval is *spreading activation*. This means that when a certain concept becomes active, all related nodes will become active as well. Spreading activation starts at a node and spreads through the links across the network.(Ashcraft, 2006)
An example is when people hear the word '*robin*' ('*roodborstje'* in Dutch), not only that corresponding concept will activate, typically words like '*red breast*', '*animal*', '*feathers*' and '*blue eggs*' will become active as well (Ashcraft, 2006).

There are two ways of representing word meanings in a network fashion: one node in the semantic memory represents one full word meaning, or the meanings are represented as an activation pattern in which the nodes function as a sort of units of meaning (Gaskell, 2007, 162-169).

Today, the last representation (the distributed representation) is favoured over the first one (the local representation). Likewise, for cases like phonology spreading activation patterns are assumed as a likely representation (Gaskell, 2007).
With these new ideas, seeing the memory as a network becomes more difficult; it is more convenient to think in terms of small networks that all belong to different levels of analysis, layering on top of each other, and mutually connected.

2.3.2. Ambiguous words

When reading a sentence that contains an ambiguous word, we can determine which meaning is intended with the aid of the context. Without context every sense of the word can be activated, but you cannot find out which meaning is referred to. Dominant meanings are more likely to have a great amount of representations and will be accessed more easily than subordinate meanings (Gaskell, 2007).

One might say that the processing of an ambiguous word is harder than the processing of a non-ambiguous word. Often, this is the case, but things are a little more complicated: in some situations, ambiguity can have a beneficial effect.

Of the main tasks used in studying ambiguity, lexical decision tasks are frequent. In a lexical decision task, a participant has to distinguish whether words are existing or non-existent words. The collected results are used to gather knowledge on the organisation of the mental lexicon and the semantic memory. Other principles commonly used in these studies, are eye-tracking and priming.

2.3.3. The advantage of ambiguity

In lexical decision tasks it is generally found that decisions on ambiguous words are faster than decisions on non-ambiguous words (where the words are matched on frequency and concreteness). Ambiguous words have more connections in the network, for every concept. Because of this, searching for one of the possible meanings of a read word, yields a result faster, than when searching for a non-ambiguous word, by chance (Borowsky, R., & Masson, 1996; Jastrzembski, J. E., & Stanners, 1975; Kellas, G., Ferraro, F. R., & Simpson, 1988).

2.3.4. The disadvantage of ambiguity

Things are different for tasks based on semantics, when more than solely lexical decision is needed. For tasks where full or almost full activation on the semantic level is needed, it is generally expected that response to ambiguous words is not faster than for non-ambiguous words. Eye-tracking results involving the amount of time looked at words, suggest that in the case of balanced ambiguous words (meanings are equally distributed), there is no difference with the matched control words (Duffy, Morris, & Rayner, 1988; K Rayner & Frazier, 1989).

However, when considering biased ambiguous target words (words with a dominant meaning, and one or more subordinate meanings), there is a difference when one of the subordinate meanings is instantiated: subjects look longer at the ambiguous words, than at the control words (Binder, K. S., & Rayner, 1998; Binder, 2003; Duffy et al., 1988; Rayner, K., Pacht, J. M., & Duffy, 1994). This is called the *subordinate bias effect* (Pacht, J. M., & Rayner, 1993; Rayner, K., Pacht, J. M., & Duffy, 1994).

A possible explanation for this subordinate bias effect is that when reading the ambiguous word, both meanings will be activated; the dominant meaning is stronger in connections than the subordinate meaning (Rayner et al, 2006). But because the prior context biases *this* meaning, conflict arises between the meanings. The results of these studies indicate that we use context for the determination/disambiguation of proper meaning.

Tasks involving association-decision (asking participants how related two words are), as well as semantic categorisation tasks (choosing in which semantic category -for example, *living things*- a particular word is considered) further confirm the idea that reaction times are longer with ambiguous words, when determination of meaning is experimented (Gaskell, 2007).

2.4. Conclusion

2.4.1. Conclusion

Language is seen as a mental process, existing of multiple sub processes. Word sense disambiguation (WSD), the determining of meaning of (ambiguous) words is one of these processes. We can divide the comprehension of language to different levels, amongst which the phonological and the semantic level. On the semantic level, we fetch word meaning from the semantic memory. The semantic memory can be modelled as a network. In this network, spreading activation constitutes the process of word meaning retrieval. When reading or hearing a word, phonological or orthographic nodes are activated, which subsequently activate semantic nodes.

Without context, ambiguity can be advantageous or detrimental. In other words, due to ambiguity reaction times can be shorter or longer with particular tasks. Especially for lexical decision tasks ambiguity is beneficial, because of stronger feedback from semantic level to orthographic level, for ambiguous words having multiple representations on semantic level. In tasks involving (recall/determinatin of) meaning, ambiguity has an elongating effect on reaction times.

Studying ambiguous words where context is present, ambiguity causes delays, because reading or hearing and incorporating context -so to strive to coherence of these pieces of information- concerns meaning as well. Results from eye-tracking studies indicate that people use context to disambiguate and that initially, all senses of an ambiguous word are activated.

2.4.2. Discussion

Current knowledge of WSD within psycholinguistics was outlined. Critical remarks can be made for all studies and paradigms, and this suggests that research on WSD is not finished. Especially connecting to autism, it remains the question how *fundamental* and *specific* the problem of ambiguity precisely is. That is why a new experiment is conducted.

3. Experiment

The difficulties for people diagnosed with ASD that involve lexical ambiguity are outlined in chapter 1. The need for an experiment was posed. To test whether there is a difference in use of context when disambiguating homonyms between individuals with autism and typically developing individuals, a novel experiment was set up.
The experiment is designed to look for differences in performance: scores of choosing subordinate meanings of homonyms from words without context, or with context condition. More precisely, a shift in performance from without to with context condition is explored. A possible difference between shift in groups with autism and in a group of typical development was researched.
As hinted previously in the earlier mentioned research questions, some hypotheses about the results are stated:
Hypotheses

- *It is expected that typically developing individuals use related sentence context to disambiguate meaning of homonyms (e.g. strive for central coherence).*
  Specifically, one might expect these subjects to choose for dominant meaning in words presented without related context, and shifting to subordinate meanings when context, relating to that specific subordinate meaning, *is present*.

- *Because of the weak central coherence theory, and earlier experiments involving ambiguity and autism, it is expected that individuals with ASD show impairment or lack in use of sentence context to disambiguate homonyms.*
  Specifically, a smaller or non-existent shift to subordinate meaning is expected, when shifting to words with same contexts.

3.1. Methods

3.1.1. Participants

Descriptives
Thirty participants were asked to fill in the questionnaire. Sixteen adolescents with high-functioning autism (IQ>70) participated, as did fourteen typically developing individuals, matching on age, gender[2] and education[3].
There was no distinction made for the type of ASD as in the most recent DSM-V (APA, 2013) these were merged to be covered under the same term.
All thirty participants had Dutch as their native language, as this was an important prerequisite to be able to properly participate in the experiment, that uses Dutch ambiguous words.

Recruitment
Multiple institutions were contacted in writing and by telephone for the acquisition of young individuals with autism, in particular different locations of subsidiary organisations of JADOS[4]: Stumass, Capito and IVA. Those interested to participate were found in the cities of Eindhoven and Nijmegen. Communication ran through the residential supervisors of the different houses for guided living, setting up appointments per location.
Recruitment of typically developing individuals went through word-of-mouth, and my own network. 14 participants were found, spread through the country.

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[2] Generally only 1 female is diagnosed with autism, as opposed to 4 males (Fombonne, 2009)
[3] No direct IQ scores were used, but all thirty participants completed secondary education
[4] http://www.jados.nl offers guided living in the form of organisations Stumass for higher education students with autism, Capito for the Dutch MBO education students with autism, and IVA for working people with autism.

3.1.2. Materials

Experimental materials consisted of 30 sentences, all having context sentences, but only half of them actually appearing in context per experiment (see for details, *Task*).
Each sentence contained a lexically ambiguous word, a homonym. After each sentence the participant was asked to choose for one of two meanings for the homonym: one of them being the dominant meaning, one the subordinate, with this fact *not* appearing on screen.
Sentences were 3 to 8 words in length, and the contexts were 40 words in length, with a margin of 2.

Homonyms and their meanings
Acquisition of ambiguous words proceeded via own brainstorming, with the help of others, and research online. Checking for whether being a homonym, and more importantly, the meaning distributions of these homonyms, went through the Small World of Words (SWOW) project database (Deyne, Navarro, & Storms, 2013), which *"started at the Experimental Psychology department of the University in Leuven (Belgium) in 2003 and already resulted in the largest available network of word associations in Dutch (over 5M responses) and English (over 1M responses)"*[5], as of May 2016. This database contains word associations for most common Dutch and English words.

The list of homonyms obtained, was checked for having multiple distinct meanings, and was filtered to have 30 homonyms in the end that had a clear dominant and subordinate meaning. Distributions of meaning attributions for the used homonyms can be found in the Appendix C.

After recalculating this table of distributions, one sentence was found to have the wrong context. In this case, the context did not have the property of pushing in the subordinate direction; instead it strived for the already dominant meaning. Therefore, this question can be regarded as an outlier. Upon learning of this fact, analysis was carried out a 2nd time, to see if the results were the same, more on this is described in the Results section.

Randomisation
Order of questions, as well the order of the two answers per question, was randomised, according to widely used and cited service Random.org (2016), with randomisation processes based on *atmospheric noise*.

3.1.3. Questionnaire

Before the 30 homonym-sentences and their questions for meaning, not only instruction was given. A couple of standard demographic data was asked to fill in. After the experimental questions, participants were asked to fill in some additional questions about the whole of the experiment as well, for interpreting purposes.
For the precise questionnaire used, including the contexts for each target-sentence, see Appendix B.

[5] http://www.smallworldofwords.com/new/visualize/

3.1.4. Task

To examine whether individuals with ASD have more difficulty using sentence context to make decisions regarding homonyms, participants were given 15 sentences with preceding context, and 15 sentences without preceding context. They were asked to choose from two meanings of a homonym that was contained in the sentences. Each question enforced to choose between two meanings, a *dominant* and a *subordinate* meaning of the target homonym word. There was no countdown on the time that participants took for questions. When context was present, these parts of a sentence contained meanings associated with the subordinate meaning of the homonym, without using words that are seen as direct associations of the homonym. (Controlled for, using the SWOW database)

For example, there was a Dutch sentence on something being "light" ("licht" in Dutch), possibly meaning "light" as opposed to "heavy", or "light" from a light source. In the SWOW database the Dutch word "licht" was found to have the meaning of a *light source* as dominant meaning, and the *not-heavy* meaning as subordinate (also see Appendix C), so when this particular target sentence appeared *with* preceding context, this context pushed to the sense of *not-heavy*, the subordinate meaning.
See that same example below:

Condition:	*Without context*	*With Context*
Context:	-	Iemand gaat verhuizen. Er zijn veel spullen die gedragen moeten worden, en het duurde even voordat alle meubels en dozen naar binnen waren gedragen. Toch leek het uiteindelijk minder werk te kosten dan gedacht.
Sentence:	"Dat is wel fijn, **licht**."	"Dat is wel fijn, **licht**."

Table 1: Experimental question outtake, without and with context conditions

One half of the ASD group received 15 homonym words with context, 15 without; and the other half of the group received the same words, but with the conditions of whether containing context *swapped*, so the *other* 15 homonyms with context, and the other 15 without. These repeated measures in this crossed design were counterbalanced for all participants. The same process went for the typical development control group. For everyone randomisation was used for the sentence order, to prevent order of question-sets or order of homonyms having an effect on the result. (As earlier mentioned, one of the questions contained the wrong context, and measured for the switched dominant and subordinate identifiers.)

3.1.5. Procedure

Carrying out experiment
Experiments were carried out in the comforts of participants' own homes; for people with ASD, the already described guided living areas. Quite, common rooms were used, with distractions such as other residents, or noises not present. For each participant a laptop was used to carry out the experiment itself. A couple of times this was a different laptop, but it was made sure the same resolution and screen size, as well as brightness, was used.
After introduction (via the residential supervisors), spoken instructions were given minimally and to all participants of that home at once. Further instruction was

presented on screen, to participants individually. Full details of instructions given can be found in the Appendix A.

Consent form

A consent form was handed out, and requested to be filled in upon the participant finishing the experiment. This form stated the participant's permission (first signee) to use his/her answers for the sole purpose of this research, and required the pledge of the examiner (second signee) to handle all data respectfully and secured, to not share the data with others and to guarantee that the data will be destroyed after five years.
For full details, please find the consent form in the Appendix D.

2.1.6. Pre-processing

Processing of the data underwent several steps before analysis was possible. Steps are described below:

- Data was stored directly in *.csv files, password protected on the laptop of the examiner.
- These data files were subsequently imported in an Excel file (again password-protected), and several move-operations were used to merge the data into a clear table with one measurement per row, so a different row for every stimulus-answer.
- Recode-operations were used to replace the chosen answers with their respective *dominant* or *subordinate* identifier; 0 was used for *dominant*, 1 for *subordinate.*
- Data was imported in an SPSS file, as repeated measures, 30 subjects x 30 questions counting for 900 rows.
- Recoding and compute operations were used to make the SPSS data file fit for repeated measures analysis. New variables were created for the sum-scores of chosen subordinates, respectively for context and non-context, thus resulting in two sum-variables.
- To account for the proportions to the total amount of questions in these two conditions, two additional variables were computed using SPSS, *SumNocontextProp*, and *SumContextProp* (the two previous described sum variables, divided by 15 each).

3.2 Results

3.2.1. Experimental design

A two-way mixed design (fully crossed factorial) was chosen for this experiment, with as between-subject factor the passive observation of whether the participant was diagnosed with Autism Spectrum Disorder or not (resulting in the two groups ASD and Typical), and as within-subject condition, the presentation of preceding context vs. no-context. The dependent variable was the subordinate score, calculated as the sum of chosen subordinate meanings in the two respective conditions.

3.2.2. Analysis technique

This experiment and its following analysis test for interaction of the between-subject and the within-subject factor. That is, whether there is an interaction between having autism or not, and choosing subordinate meanings in context or no-context conditions. A two-way ANOVA (GLM repeated measures test) was chosen as analysis technique. The dependent variable was recomputed as the proportion of the subordinate score, so the previously described score divided by the total of questions in that condition (15) resulting in two variables with continuous scores, between 0 and 1.

To reiterate: the main hypothesis is that the score changes over condition for typically developing individuals, and not so much for people with ASD. Also, it is expected that in the condition without any context, the autism and Typical group perform similar, whereas in the condition, the Typical group might expected to be performing better. This would mean the Typical group is expected to be performing better, averaged overall

In statistical terms, the (H_A) hypotheses can be stated as:

- There is a difference in performance between the Typical development and the ASD group
- There is an interaction effect between the group and the condition factors = the effect of group on performance is dependent of the condition, and vice versa.

3.2.3. Descriptive statistics

Demographics

Of the 30 participants the age ranged from 19 to 29 with a mean of 22.5 (σ=2,6).
For the ASD group this was comparable (N=16, M=22,1, σ=2,1) since it was matched with the Typical group on age (N=14, M=22,9, σ=3,1). Only 10% of the participants was older than 25. 10% of the participants were female, 90% male (ASD: 12,5% female, Typical: 7,1% female) (prevalence of ASD in males is found to be higher across global population (Newschaffer et al., 2007)).
Professional status was spread, but participants were mainly student (87,5% in ASD, 66,7% in total) or working (50% in Typical, 30% in total).
Education was spread as well, with highest education in ASD: 43,8% higher education (HBO or university), 56,2% had high school or MBO as education. In the typical development group 85,7% had higher education, 14,3% lower.

Experiment

Looking at the questions asked without context, the typical development group chose for subordinate meaning in 41,9% of the time (averaging over the 30 questions), and the ASD group chose for subordinate meanings 47,9% of the time.

Exploring the subordinate scores for both groups in both conditions, gave the following means and standard deviations:

Measure	ASD/Typical	Mean	St. Dev. (σ)	N
Subordinate-score (proportionalised) without context	Typical	.4190	.11819	14
	ASD	.4792	.11213	16
	Total	.4511	.11703	30
Subordinate-score with context	Typical	.8095	.11652	14
	ASD	.7042	.17549	16
	Total	.7533	.15771	30

Table 2: Descriptive statistics of all participants performances in experiment.

We can here already see a difference between proportion of subordinates chosen by the typical development group in the different conditions, with a consistent standard deviation, and a much lesser shift across conditions by the ASD group, with the spread quite larger in the Context condition. For a full boxplot of these data (in which you can see the spread in more detail), see below, under the assumption for outliers.

3.2.4. Assumptions

Before a two-way ANOVA analysis can be carried out, some assumptions need to be satisfied.

- *Data needs to be normally distributed*
  Normality of data was tested using the proportion of subordinates per subject (dependent variable) among the two different conditions (within-subject factor) in the two different groups (between-subject factor). These variables were tested using the Shapiro-Wilk test and found to be normally distributed (all p>0,05) (not rejecting the H_0 hypothesis that the data resembles a Gaussian distribution.) All these results had the same conclusion in the 2nd analysis with 29 of the 30 questions: normality was assumed with all p values >0,05.
- *Data has to contain no outliers*
  As can be assessed by inspection of a boxplot, no outliers were detected in data of the groups ASD and Typical for the respective subordinates proportion scores. Also visible in the boxplot is the spread of the data, which in the Context condition is much larger for the ASD group. (All these results had the same conclusion in the 2nd analysis with 29 of the 30 questions: no outliers)

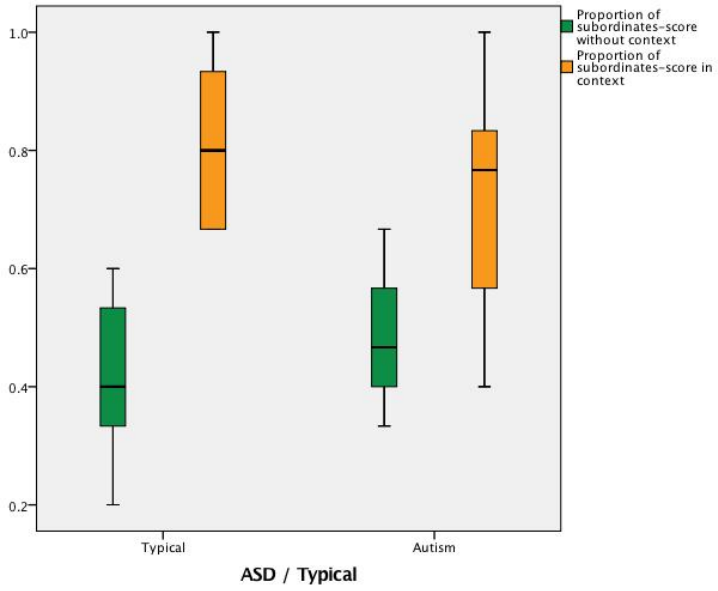

Figure 2: Boxplot of all participants' performances

- *Homogeneity of variance*.
  There was homogeneity of variances, as assessed by Levene's test of homogeneity of variance (no context: p=0,745, context: p=0,059). (All these results had the same conclusion in the 2nd analysis with 29 of the 30 questions: no context: p=0,856, context: p=0,110)
- *Assumption of sphericity*.
  Determining whether this assumption is met, happens by means of Mauchly's test of sphericity. Because of only having two conditions for the within-subjects condition, the ε-values are 1.000 and indicate perfect sphericity. So this assumption is automatically met.
- *Assumption of equality of covariances.*
  There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices (p=0,547)(All these results had the same conclusion in the 2nd analysis with 29 of the 30 questions: p=0,597)

3.2.5. Statistical analysis

Tests of Within-Subjects Effects

The results of two-way interaction and significance scores are illustrated below, indicated in the Context * ASD_Typ row.

Measure: performance on subordinate scores	Type III Sum of Squares	df	Mean Sq	F	Sign. (p)	partial η^2	Observed power
ASD_Typ	.008	1	.008	.359	.554	.013	.089
Context	1.414	1	1.414	96.079	.000	.774	1.000
Context * ASD_Typ	.102	1	.102	6.945	.014	.199	.720
Error(Context)	.412	28	.015				
Error(ASD_Typ)	.597	28	.021				

Table 3: statistical results of analysis for Between, Within and Interaction effects.

We can conclude that there was a statistically significant interaction between the group-factor (ASD/Typ.) and context-condition on proportion of subordinates chosen, $F(1,28)=6{,}945$, $p<0{,}05$, partial $\eta^2 = 0{,}199$. (All these results had the same conclusion in the 2nd analysis with 29 of the 30 questions: $p<0{,}05$ (0,018) and $F(1,28)=6{,}376$)

The existence of two-way interaction between group (ASD/Typical) and condition (no context/context) factors can be observed by visually inspecting the profile plot after running the two-way ANOVA.

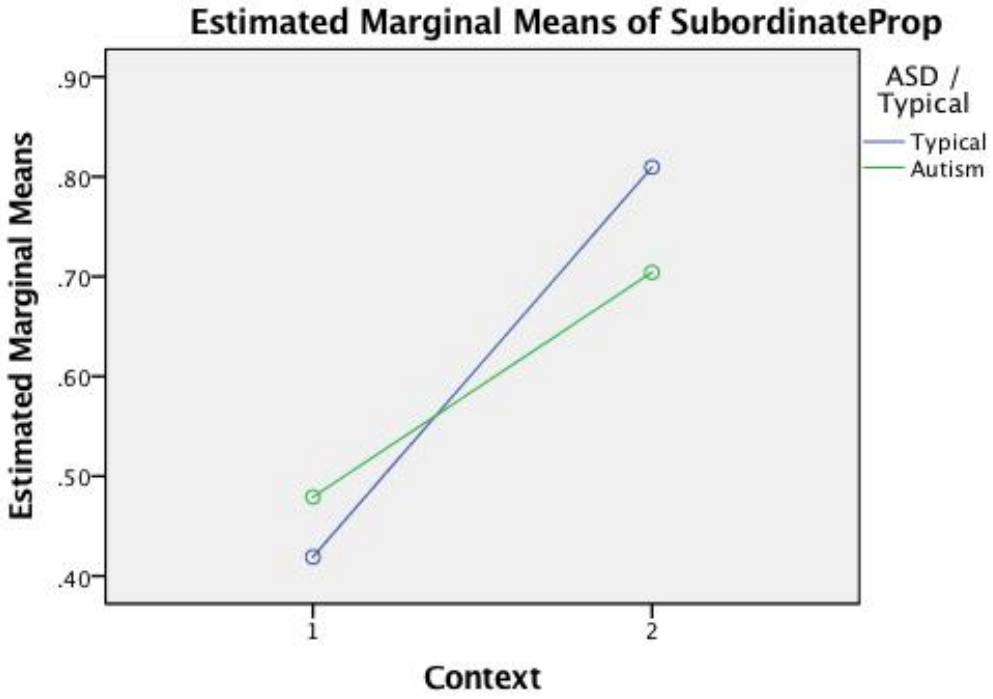

Figure 3: Profile plot for interaction. 1= No Context, 2=Context condition

Simply put, the lines are **not** parallel, so one *might* expect an interaction effect. Because the lines for the ASD and Typical development groups cross over the conditions, it is *likely* to find a significant interaction effect.

Between-subject effect
The effect of group, overall, was not significant, as can be seen in Table 3 ($F(1,28)=0,359$, $p=0,554$, partial $\eta^2 = 0,013$, in 2nd analysis: $F(1,28)=0,251$, $p=0,620$, partial $\eta^2 = 0,009$) This tells us there is no significant difference between the Typical Development and Autism groups when looking at *overall* performance on the questions in the experiment, *disregarding* the co-presence of context.

Differences in no-context condition
As could be seen earlier in the boxplot, the "beginning" condition so-to-speak, the condition when there is no context present, showed a difference between the two groups.
An independent samples t-test was run to determine these differences. The subordinate score was higher for the 16 ASD participants ($M=0,479$, $\sigma=0,112$) than for the Typical developing participants ($M=0,419$, $\sigma=0,118$). This difference was not significant (mean difference = -0,06, 95% CI [-0.15, 0.03], $t(28)=-1,429$, $p=0,164$, $d=0,52$) (In 2nd analysis: $t(28)=-1,486$, $p=0,149$).

This p value means there is a 16,4% chance of getting a mean difference between an ASD and Typical group at least as large as the one obtained, if the null hypothesis is true (the H_0 stating that there is no difference between the group means). Difference in no-context condition can be seen in the bar chart below.

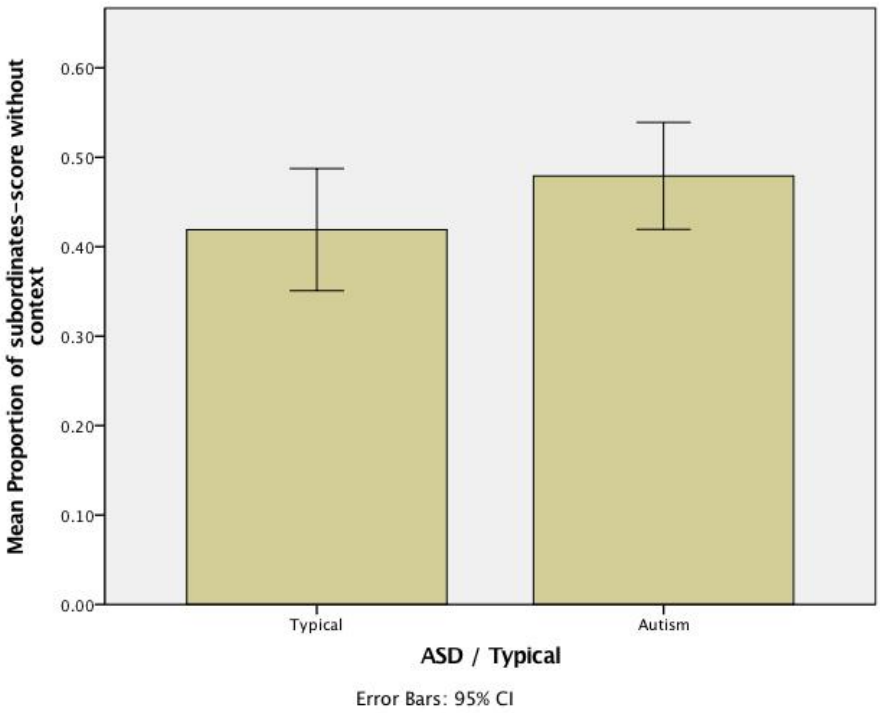

Figure 4: bar chart of group differences in no-context condition

The last question was found to be incorrect according to the experiment setup (see *2.1.2 Materials*). After initial analysis, this question was considered as missing value and a second analysis was run. The 2nd analysis results yielded slightly different values (mentioned throughout the text) but had the same conclusions.

3.2.6. Conclusion

There were no outliers, as assessed by boxplot. The data was normally distributed, as assessed by Shapiro-Wilk's test of normality (p > ,05). There was homogeneity of variances (p > ,05) and covariances (p > ,05), as assessed by Levene's test for homogeneity of variances and Box's M test respectively. Mauchly's test of sphericity indicated that the assumption of sphericity was automatically met for the two-way interaction.
There was a significant interaction between the group-factor (ASD/Typ.) and context-condition on proportion of subordinates chosen (F(1,28)=6,945, p<0,05, partial η^2 = 0,199). The effect of group, overall, was not significant (F(1,28)=0,359, p=0,554, partial η^2 = 0,013).
The difference in the no-context condition, between groups, was not significant (t(28)=-1,429, p=0,164).

4. Discussion

This thesis tried to add to the knowledge of the weak central coherence theory for Autism Spectrum Disorder (Frith, 1989; F. Happé & Frith, 2006). Existing literature was summarized, and a novel designed experiment was conducted, in order to answer research questions. I will elaborate on these questions. After that, in what way these results can be applied, is outlined. Some limitations are discussed, and lastly, conclusions are summarised.

4.1. Research questions

Reiterating, the main research question of this thesis, was:
"Does contextual information resolve lexical ambiguity for individuals with autism spectrum disorder?"

The different sub-questions were used to answer this question, so first, I will try to answer these sub-questions.

4.1.1. Sub-question 1

To understand this topic, there was the need to see if:

1. *Is ambiguity a problem that is resolved within ASD, in the same way as it is for typical developing individuals?*

To resolve different kinds of linguistic ambiguity, people use context (Gaskell, 2007). For tasks involving visuo-spatial context, individuals with ASD are facilitated by the use of context to a comparable extent as typical developing individuals do (López & Leekam, 2003). In tasks concerning lexical decision or semantic categorisation, where ambiguity seems to initially be an advantage (Borowsky, R., & Masson, 1996; Jastrzembski, J. E., & Stanners, 1975; Kellas, G., Ferraro, F. R., & Simpson, 1988), people with ASD were facilitated by verbal context as well (López & Leekam, 2003).

However, when meaning is involved, studies for resolving homograph-ambiguity (F. G. E. Happé, 1997; Jolliffe & Baron-cohen, 1999) and auditory presented sentence ambiguity (Jolliffe & Baron-cohen, 1999) showed that use of context, and therefore the strive for central coherence, was impaired for individuals with high-functioning autism. It seems that there is a specific issue with lexical ambiguity and processing meaning, for ASD.

4.1.1. Sub-question 2

Focusing in, subsequently, we can wonder:

2. *Does the use of context resolve ambiguity for people with ASD, in a task for meaning of homonyms?*

A novel experiment was designed and conducted, that studied the use of preceding context to switch to subordinate meanings (instead of dominant) of homonyms when context pushed to do so, between ASD and Typical Development groups. This brought some hypotheses to mind.

These hypotheses were stated as:

- *It is expected that typically developing individuals use preceding sentence context to disambiguate meaning of homonyms (e.g. strive for central coherence).*
- *Because of the weak central coherence theory, and earlier experiments involving ambiguity and autism, it is expected that individuals with ASD show impairment or lack in use of sentence context to disambiguate homonyms.*

This brought forward the statistical testable hypotheses. Those are discussed below.

4.1.1.2. Sub-question 2: statistical hypothesis 1

- *There is an interaction effect between the group and the condition factors.*
-

An experiment for two groups: ASD and TD, compromising questions without and with preceding context, was set up. There was found to be a significant interaction effect between the group-factor (ASD/Typ.) and within-subjects condition (no context/context). The experiment controlled for age, and male ASD prevalence being much higher (Fombonne, 2009), and addressed adolescents with high-functioning, all having at least finished high-school.

The performance was measured as the proportion of subordinate meanings chosen, expected to be low without context, because of choosing dominant meanings, and expected to be high, when sentence context pushed towards subordinate meanings. However, as could be seen from the profile plot (Figure 3), and taking into account the boxplot (Figure 2), individuals with autism showed less clear a shift towards using context, as TDs did.

The interaction effect states that the influence of preceding context on the performance, *depends* on the category of groups: having autism or not influences to what extent context is used in disambiguating homonyms.
This seems to confirm the prediction from the central coherence theory that individuals with an ASD will be impaired in ability to achieve coherence (F. Happé & Frith, 2006; F. Happé, 1997) .

4.1.1.2. Sub-question 2: statistical hypothesis 2

- *There is a difference in performance between the Typical development and the ASD group*

There was no significant between-subject effect found overall *(p*=0,554) which suggests the overall use of context for disambiguating homonyms is not so different between ASD and TD. However, that is when conditions with *and* without context are present. In real life, there is always context in the form of an environment, and also almost always lexical context, in the form of conversation, texts, etc.
Also, looking at the spread in the boxplot (Figure 2), you could say the overall effect is somewhat leveled out, because of the ASD group choosing subordinates somewhat more, in the initial condition, without context already. When use of context is required to choose the subordinate meaning that is of importance in a particular sentence, the ASD group showed a huge spread, and scored lower than TD.
The between-group effect is not statistically significant, but, I argue, also not practically that significant, because the influence of context in real-life examples is always present. There will always be an influence of such a condition, as well as (as is evident from the interaction effect) the influence of having ASD or not.

Conclusion
Also, these results suggest that lexical ambiguity is a fundamental issue within ASD. Whereas diagnosis and characterisation of ASD happens on a high level traits, such as communication and obsessiveness, the problem of dealing with subtleties in social communication, such as homonyms pose, seems to be already distinguishing autism, on such a specific, fundamental level. This is something that has to be kept in mind, designing therapies, and as a possible extension of the diagnosis process of autism.

4.2. Application of results

To answer sub-question 3, this paragraph is used, to discuss the implications in more detail.

4.2.1. Sub-question 3

3. *Can results from measurements form input for future Artificial Intelligence (AI) applications, to help individuals be diagnosed with ASD?*

4.2.2 Diagnosis

Current diagnosis
Diagnosis of an autism spectrum disorder is still solely dependent on judgement of clinicians. Their intuition for the social interaction of a child and interviews with parents serve as diagnostic tools. Social skills like eye-contact, facial expressions, postures and gestures are observed. These interviews are standardized in forms of Autism Diagnostic Interview-Revised (ADI-R) (Rutter, M., Le Couteur, A., & Lord, 2003) and the Autism Diagnostic Observation Schedule (ADOS) (Lord, C. et al 2000), but autism remains a disorder specified on behavior. There is no blood test, no functional imaging, nor a genetic screening that can make a diagnosis of ASD (Volkmar et al. 2004), and no biological markers are used in diagnosis (Anagnostou & Taylor, 2011).

The observational judgments that are quantified in these mentioned standardized protocols are not precise, as well as subjective. There is disagreement of clinicians on individual diagnoses, which poses difficulties for both the selection of appropriate treatments for patients, and for the reporting of results of population-based studies (Klin, A. et al 2000; Volkmar, F., Chawarska, K., & Klin, 2005). Also, the behavioral diagnosis as it is used today, requires considerable time investment on the part of parents and clinicians. (Wall, Dally, Luyster, Jung, & DeLuca, 2012)

The practice of diagnosing ASD not only varies widely in terms of standards and timeframes, it appears that families sometimes wait as long as 13 months between initial screening and diagnosis (Wiggins, L. D., Baio, J. O. N., & Rice, 2006) and even longer, when being part of a minority population or of a lower socio-economic status (Bernier, R., Mao, A., & Yen, 2010). These delays can directly translate into delays in the speech-delivery and behavioural therapy that has significant positive impact on the development of a child, especially when this is delivered early (Hadwin et al., 1998; Pinto-Martin et al., 2008).

However, neuro-imaging studies and studies with infants suggest there are actually fundamental differences that could be used to make diagnosis, and thus further treatment(-selection) thereupon, faster and more reliable.

Neuro-imaging
One of the most replicated findings in neuro-imaging is early brain overgrowth for people with ASD, which is also associated with atypical functional and structural connectivity in the brain. Also cortical thickness and surface area need to be examined further in combination with this, because it could shed light on early neuroanatomical differences, indicators of developmental events in ASD (Anagnostou & Taylor, 2011). This atypical connectivity could be a cause for problems with complex information processes like the strive for central coherence.

As Anagnostou & Taylor argue in their review of different neuro-imaging studies for ASD, methods using with fMRI, neurochemical studies and studies for structural connectivity could be combined within the same cohort of subjects and in a developmental manner. This focus could highlight shared developmental abnormalities in ASD. It could like imaging findings to underlying neurobiology, which is a necessary step to further facilitate experimental therapeutics. (Anagnostou & Taylor, 2011)

Furthermore, reductions in size of the corpus callosum are found in autism (Hardan, Minshew & Keshavan, 2000; Piven et al., 1997), as well as decreased functional connectivity between hemispheres (Egaas, Courchesne & Saitoh, 1995; Piven et al., 1997). This too, can lead to decreased information integration capacity (Just et al., 2004; Schultz, Romanski & Tsatsanis, 2000).
Imaging data suggests there is a temporo-frontal pathway lateralized in the right hemisphere for prosody and a similar pathway lateralized in the left hemisphere for syntax/semantics, and that these pathways are connected via the corpus callosum (Friederici & Alter, 2004), resulting in difficulty integrating information from prosody with other aspects of language (Diehl et al., 2008).

Infants
As neuro-imaging could begin to play a part in early diagnosis of ASD, also experimental study of infants has shown that deficits in eye-contact is not only an already wide-known trait in autism, its early onset shows a clear decline in eye-fixation, for infants of 2 to 6 months old, later diagnosed with ASD. This pattern was not observed in infants not developing ASD. (Jones & Klin, 2013)

Further techniques
On top of infant study, and neuro-imaging techniques, tests like the one described in the experiment of this thesis, could play an extra role in (early) diagnosis.
As ambiguity studies for autism with homographs (Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003) have shown, as well as the experimental results presented here, lexical ambiguity seems to be a major, fundamental problem, showing differences of performance on a low/sentence level.

Using these results, tests can be designed, to see if people show little difference in performance of disambiguation, across conditions of context and no-context. Namely, these results could be an indicator of poor integration of context and weak central coherence, and therefore autism.
Databases with large data sets on lexical and structural information could be used for implementing, like the already described Small World Of Words (Deyne et al., 2013) or for example WordNet (Princeton University, 2010).

Note that solely, such a test could never be a direct indication of ASD and in isolation could not yield a diagnosis. Results like the ones described could have many more other causes, like learning impairments.

That is why such proposed extra tests are suggested to be an *extra* tool in diagnosis. The process could be a short test to prioritize further diagnosis.

Neuro-imaging or longitudinal studies described above could serve as such an early extra tool as well, with an important difference that these would take a lot of effort and time; a lot of commitment before moving on to a therapeutical diagnosis. However, when clear, conclusive neurobiological indicators would be found for autism, these would of course be highly suggested methods as well.

Machine Learning and the ADI-R
A last suggestion for help in diagnosis comes from machine learning. The earlier described standard interview used in diagnosis, the Autism Diagnostic Interview-Revised (ADI-R) consists of 93 questions and can take up to 2,5 hours (Wall et al., 2012). In a study by Wall et al. from 2012 machine learning techniques were studies to reduce this amount. They found that the Alternating Decision Tree (ADTree) had high sensitivity and specificity in the classification of individuals with autism. The ADTree classifier consisted of only 7 (of the 93) questions, 93% fewer than the full ADI-R interview, and performed with larger than 99% accuracy when they applied it to independent populations of individuals with autism, misclassifying only one out of the 1962 cases used for validation. This could be a major improvement for an early extra tool in diagnosis.

4.2.3. Therapy
Also, I think the results of this thesis can add to the therapies for people with ASD. When considering lexical ambiguity as a very specific issue, posing difficulty for individuals with autism, therapies and social stories (Gray & Garand, 1993) could be developed that focus on use of context.

Previous research has already shown that people with autism feel comfortable in predictable environments. More particularly, they enjoy interacting with computers. This could be explained by the attention of people with autism, which tends to be fixed on isolated objects apart from the surrounding area. Computers can break into this world by focusing the attention on the screen, so that external events can be ignored more easily (Murray, 2011).
Computer-based therapies and education are seen as an effective aid in teaching language to children with autism for a time now (Hershkowitz, 2000). We can conclude that the help of computers is highly suggested when implementing possible tests described above. Interactive educational environments, for example based on the use of robotics, is currently a widely researched and implemented area (Kientz et al., 2013; Ricks, D. J., & Colton, 2010).

This thesis suggests that also in this field, a focus should be developed on integrating context, especially for lexical ambiguity; as opposed to the fairly well performance on viso-spatial ambiguity (López & Leekam, 2003).

4.3 Limitations

4.3.1. Critics on Central Coherence theory

One main point of critics of the weak central coherence theory was that it does not account for the whole range of autistic disorders. A study by (Jarrold & Russell, 1997), cited in (F. Happé & Frith, 2006) showed that weak central coherence occurs only in some part of the population with an autistic disorder.
For this, and more reasons, Happé and Frith adjusted the theory in 2006. One of the changes consisted of the deficit in central processes, that manifested itself by failing to come to a overall meaning, being changed from a primary to a secondary problem, where the superiority in local or detail oriented processing gained more importance. A more remarkable adjustment was the changing of the descriptive nature, to an acknowledgement that weak coherence is but an aspect of cognition within autism, instead of *the* determining factor for deficiencies in social skills that are present in people with ASD.

4.3.3. Experiment

The experiment carried out in this thesis contains some limitations, which are described below.

Wrong question
Upon rechecking the distributions table of the 30 homonyms used in the experiment (see Appendix C), the last one was found to have the wrong *dominant* and *subordinate* identifiers, and because of this, the wrong preceding context according to the experiment design.

Meaning distributions
An important limitation of this experiment to be noted, is that it did not control for the exact distributions of *dominant* and *subordinate* meanings. That is, in the results, scores were based on how many subordinates chosen in the different conditions overall. However, sometimes a subordinate meaning in no-context is chosen (in previous databases like SWOW) 10% of the time, and sometimes 30%, for example. This experiment only checked for a meaning *being* notably subordinate.
A more detailed experiment should:

- Only use homonyms with subordinate and dominant meanings with same distributions, or because this is practically impossible
- account for the precise distributions, when computing a more advanced score, that can be used as a measurement in a similar experiment as the one described here.

4.4. Conclusion

In this thesis, a theoretical background was given on autism (ASD), and the difficulties individuals with ASD encounter with integrating information/context, especially with lexical ambiguity. A novel experiment was set up to see if people with ASD can disambiguate homonyms using preceding sentence context, and the implications of this experiment were discussed. This resulted in answers to different sub-questions. Below, the main research question is discussed, as well as proposals for future research.

4.4.1. Research question

"Does contextual information (4) resolve (3) lexical ambiguity (2) for individuals with autism spectrum disorder (1)?"

1. *Autism spectrum disorder* is a behavioural disorder that poses different kinds of issues, among which social communication.
2. Within social communication, subtleties in language, and integrating information to resolve these nuances and ambiguity are a clear problem. Much research has been carried out, and has shown that especially striving for central coherence is weakened. Integrating information used for disambiguating meaning of *lexical ambiguity* is impaired.
3. Because this ability is impaired, we try to examine how fundamental this problem is. On what level is ambiguity already a problem? This is why an experiment was carried out, requiring participants to *resolve* lexical ambiguity, choosing for specific meanings of ambiguous words.
4. In order to do so, and to inspect integrating information use, *contextual information* was added to see that if such a fundamental problem arises, does it confirm weak central coherence?

"No" is not a possible answer to this research question, because results showed that individuals with ASD actually improved performance when sentence context was added, to some extent. However, people with ASD already chose subordinate meaning somewhat more than Typical developing individuals (TDs), without context.

However, "Yes" is not a possible answer as well, because the ASD group scored lower than TDs (and with great spread) when context was added. Also, there was a significant interaction effect of group (ASD/TD) and condition (no context/context), saying that the relationship between one of these two factors (for example, having context) and the performance is dependent on the other factor (for example being ASD/TD).

So yes, to some extent preceding contextual information does add to the understanding, but this ability seems somewhat impaired, on the level of disambiguating homonyms, further confirming the weak central coherence theory (Frith, 1989).

4.4.2. Future research

A very specific problem is researched in this thesis, and implication and effect on greater fields of knowledge are suggested. However, further research is still needed for many things to become clearer:

- *Diagnosis*
  Can we actually improve early diagnosis with the help of results of studies like this one? A tool, or multiple different ones, could be implemented using homonyms and their dominant and subordinate meaning distributions, to see if individuals could be classified for further inspection of diagnosis. The same goes for studies involving homographs, and other types of lexical ambiguity.

  Also, could tests/tools like these, be integrated with neuro-imaging, or machine learned questionnaires? Again, to not diagnose in isolation, but to be an extra, for prioritizing diagnosis or treatment.

- *Measurement*
  When using results from this kind of tests, more research should be invested into computing a score or measurement for the performance on lexical ambiguity.
  A more sophisticated way of testing someone's ability to use sentence context to disambiguate meaning is needed.

- *Disambiguation*
  Could the ability of disambiguation actually be improved? Research into Natural Language Processing is already being carried out regarding resolution of lexical ambiguity (Small, S. L., Cottrell, G. W., & Tanenhaus, 2013).
  Can performance of automated word sense disambiguation be measured? If performance is well enough, could tools be developed from this, to aid individuals with ASD in integration of information?

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Appendices

Appendix A. Experiment timeline

<Welcome words, START>

<Instructions (in Dutch)>
"Welkom bij dit korte taalkundige experiment. We onderzoeken hierin hoe mensen zinnen verwerken. Bedankt dat je mee wilt doen!
Het experiment bestaat uit 3 blokken: we vragen je naar enkele personalia, erna volgt het experiment met 30 meerkeuze vragen (die duren ongeveer 15 minuten in totaal) waarna tot slot enkele algemene vragen volgen."

"Je bent altijd vrij om te stoppen (geef dat in dat geval aan aan de onderzoeker of je begeleider). Na afloop van het experiment, gaarne het toestemmingsformulier in te vullen dat naast je ligt. Je kunt het vast even doorlezen, maar je kunt het na afloop invullen."

<Personal information questions (in Dutch)>
Persoonlijke informatie

- Wat is je leeftijd? (in jaren)
- Wat is je geslacht?
- Wat is je beroepsstatus?
- Wat is de hoogste vorm van onderwijs die je hebt afgerond?

1. Je zult nu steeds een stukje tekst zien, waarin je het dikgedrukte woord moet vervangen met een woord van dezelfde betekenis.
2. Kies het antwoord dat voor jou het beste past. Er is geen tijdsrestrictie, maar probeer niet te lang na te denken; we zijn benieuwd naar je eerste ingeving!
3. Als je het niet weet, probeer dan toch een antwoord te kiezen.
4. Zodra je een vervanging hebt gekozen, kun je je antwoord niet meer veranderen.

<30 Homonym questions (in Dutch, see Appendix B) (randomized order, answer choices also)>

<General questions (in Dutch)>

- Je zag langere en korte stukjes tekst. In hoeverre hielp die tekst jou om een passende betekenis te kiezen voor het woord? (1-5, 1=Totaal niet, de lengte van de tekst maakte niets uit, 5= Heel erg, hoe langer de tekst, hoe makkelijker ik het vond om een betekenis te kiezen)
- Nu heb je steeds tekst gezien, maar wat zou, denk je, voor jou het beste werken, om te helpen bij het kiezen van een betekenis? (Door de tekst die erbij stond; Ik had niet echt moeite met zinnen; Anders)
- Heb je verder nog opmerkingen, of gedachten over de vragen, of dit experiment?

"Hartelijk dank voor je deelname! Je kunt het experiment nu beëindigen, en het - toestemmingsformulier invullen."

<END>

Appendix B. Questionnaire (in Dutch)

	woord	***Zin + evt. context***	***Antwoord Subordinate/dominant***
1	Licht	Iemand gaat verhuizen. Er zijn veel spullen die gedragen moeten worden, en het duurde even voordat alle meubels en dozen naar binnen waren gedragen. Toch leek het uiteindelijk minder werk te kosten dan gedacht. "Dat is wel fijn, **licht**."	**Niet zwaar**/licht van zon of lamp s/d
2	Scheiding	Bij elke kapper kun je nieuwe dingen uitproberen. Zo wilde Marie eens iets anders met haar kapsel. Ze had het nu al zo lang in een bepaalde houding, dat ze het eigenlijk een beetje maf begon te vinden. "Wat een rare **scheiding**."	**Scheiding in het haar**/echtscheiding van een huwelijk s/d
3	Schaal	Op school leer je vaak over hoe je bepaalde grootheden kan opmeten. Erg opvallend is het, maar ook verwarrend, dat je in sommige landen, dan op een andere manier doet, dan in andere landen. Die **schaal** is echt perfect.	**Schaal voor bijvoorbeeld gewicht of aardbevingen**/kom of fruitschaal s/d
4	Toets	Piet woonde tijdelijk bij Jan, omdat hij nog geen kamer had gevonden. Hij moest ook nog een boel spullen kopen, zo had Piet nog geen eigen laptop. Wel kon hij die van Jan soms lenen. "Één **toets** was niet geweldig."	**Toets van een computer**/examen s/d
5	Toast	Op het verjaardagsfeest had Piet zich verheugd. Het was een verrassing geweest voor zijn vriendin, en dat betekende veel voor haar. Hun gemeenschappelijke vrienden hielden hun glazen in de lucht, en wensten hen enkele mooie woorden toe. "De **toast** beviel hem goed."	**Proosten van champagne of iets dergelijks** / geroosterd brood s/d
6	Gerecht	Met haar adviseur ging ze naar Amsterdam. Die dag bracht wat spanning met zich mee, want wat de beslissing over haar geld zou zijn, was nog onzeker. Na afloop liepen ze naar buiten. "Zij had nogal wat commentaar op het **gerecht**."	Eten / **rechtbank** d/s
7	Aangeven	Met zijn tweeën is het veel makkelijker koken. Je kunt de taken verdelen, en je hoeft nooit ver te lopen voor keukengerei. Als je iets niet weet of iets nodig hebt, kun je het altijd vragen. "Kun je dat **aangeven**?"	Melden (bij politie/douane) / **aanreiken of overhandigen** d/s
8	Lijn	Jan ging vandaag een meeloop-dag doen op een nieuwe school. Eerst reisde hij een uur met de trein. Erna moest hij nog even zoeken hoe hij vanaf het station naar de school zou komen. "Is dat wel een **lijn**?"	Streep/**buslijn** d/s
9	Stoppen	Marie heeft het erg druk met haar scriptie. Hele dagen zit ze in de bibliotheek om eraan te werken, maar het is bijna af. Ze vind het lastig om het los te laten nu het zo ver is. "Vanavond gaat ze **stoppen**."	Stilstaan/**ophouden** d/s
10	Trap	Jan en Piet zaten enkele jaren samen op een vechtsport. Ze konden dan lekker hun overtollige	**schop**/trap met tredes om omhoog te gaan

		energie op een goede manier gebruiken, door te sporten. Thuis keken ze ook wel eens vechtfilms. "Kijk, dat was een stevige **trap**."	s/d
11	Aas	Op vakantie regende het de hele tijd, dus zocht de familie andere dingen om de druilerige middagen en avonden door te brengen. Gelukkig hadden ze genoeg meegenomen. Pa had een leuk spel. **"Aas** is wat hij nog nodig had."	**Kaart uit kaartspel**/lokaas voor vissen s/d
12	Blad	Vandaag bezochten ze met school een natuurpark. Ze hadden onder andere een rondleiding en een workshop. School hoopte dat hierdoor de kinderen meer waardering zouden krijgen voor de natuur om hen heen. "Pak een **blad** dat je mooi vindt."	**Boomblad**/Papieren blad, om op te schrijven s/d
13	Hoop	Voor zijn werkstuk had Jan zich geen zorgen gemaakt. Hij vond het best moeilijk, maar hij had veel artikelen gevonden. Piet wees hem op een sectie in de bieb, en daar had hij méér dan genoeg aan. "Daar zat een **hoop**."	**Berg of veel**/verwachting of geloof s/d
14	Golven	Morgen gaat hij naar Spanje. Niet per se om te doen wat al zijn vrienden na de examens deden, maar om een congres bij te wonen van iets waar hij al jaren op zijn zolderkamer mee bezig was. **"Golven**, waar hij van hield."	Watergolven, op zee / **geluids-, radiogolven** d/s
15	Noot	Jan is in Tilburg vandaag, en is gespannen voor de auditie die hij daar gaat doen. Al maanden had hij zich voorbereid. Het conservatorium is waar hij altijd al van droomde. "Vertel eens iets over die **noot**."	**Muzieknoot**/noot die je kunt eten s/d
16	Slot	De hele dag had Marie zich verstopt op haar kamer, om het laatste boek in een serie te lezen. Het lag sinds gister in de winkel en ze had het nu al bijna uit. Nog één hoofdstuk te gaan. "Een interessant **slot**."	**Einde**/Slot met sleutel s/d
17	Kussen	Vorig jaar had Piet iemand ontmoet. Na enkele dates, en een paar keren logeren, hadden ze gemerkt dat de chemie aanwezig was. Ook hadden ze veel gemeenschappelijke interesses, en vinden ze elkaar heel mooi. "Het **kussen** is fantastisch."	(hoofd-)Kussen om op te slapen/**zoenen** d/s
18	Vorst	De regering had het al lang afgesproken met het buitenlandse staatshoofd, zodat alles goed zou gaan, wanneer hij neerstreek in Nederland. Ondanks dat het al vroeg donker was, zou hij 's avonds een grootse aankomst krijgen. "De **vorst** komt er volgende week aan!"	Vrieskou/**koning(in)** d/s
19	Schat	Hij had al ver gereisd, alvorens hij was waar hij wilde zijn. Hij had haar zo gemist, en nu zouden ze elkaar eindelijk weer zien. Hij was gelukkig en verliefd toen hij haar opzocht bij haar familie. "Wat een **schat** vond hij daar."	**Lieve benaming, liefste**/schat van goud, bijv. Piratenschat s/d
20	Bank	Ze liepen door de stad, Jan liet zijn familie zien waar hij nu woonde. Hij had ze al verteld over de stad, en waar hij vaak langskwam. Ze vonden het fijn eens te zien. "Daar is de **bank** waar we het over hadden!"	**Bank met geld**/zitbank s/d

21	Kraan	Terwijl ze door de stad liepen, zagen ze hoeveel er aan het veranderen was. Overal stonden nieuwe gebouwen, en er werden nog steeds nieuwe bijgemaakt. Sommige nog hoger dan de hoogste die ze kenden. "De grote **kraan** viel hem op."	Waterkraan/**hijskraan** d/s
22	Ster	Lang hadden ze ernaar uit gekeken. De late première van de nieuwe Harry Potter film. Ze keken hun ogen uit op de rode loper, want zoiets hadden ze nog nooit meegemaakt. "Ze hadden nog nooit zo'n grote **ster** gezien."	Ster aan de hemel/**filmster, beroemdheid** d/s
23	Beeld	Piet liep met Marie door zalen vol mooie authentieke Romeinse spullen. Het was vakantie en ze waren naar Rome gegaan, hun eerste vakantie samen, omdat ze allebei zo van cultuur hielden, en nog nooit in Italië waren geweest. "Kijk dat **beeld** eens!"	Foto, televisie/**kunstwerk, standbeeld** d/s
24	Pad	Laatst gingen wij wandelen, en dat beviel zo goed dat we steeds verder van de bebouwde wereld kwamen, zelfs verdwaald raakten. Doordat we fout hadden gelopen, konden we nu de route terug naar huis niet meer vinden. "Ik zie daar een **pad**!"	**Bos- of looppad, weg**/kikkerachtige s/d
25	Eng	Als je dat ene videospel speelt, waarbij je moet racen door scherpe bochten, moet je goed uitkijken. Er zitten bepaalde stukken in een route, waar je náuwelijks doorheen past met je auto. "Dat stukje is **eng**."	Bang, griezelig / **smal, nauw** d/s
26	Val	Ze hadden in de keuken nogal last van stank. Na lang schoonmaken en opruimen, bleek de oorzaak bij nog wat anders te liggen dan alleen te weinig afwas doen. Er bleek een plaag te zijn. "Die **val** moet onverwacht zijn geweest."	**Muizenval, strik** / ongeluk s/d
27	Kop	's Middags gingen Marie en Piet wat drinken bij de oma van Jan. Al haar spullen waren nog van prachtig antiek. Ze keken onder andere uitgebreid naar haar versierde kleding en oude borduursels. "Kijk eens naar die **kop**."	**Servies, koffiekop** / hoofd s/d
28	Blik	Fotograferen is één van de grootste hobby's van Jan. Hij vindt het geweldig om mensen op straat aan te spreken en, als het mag, met zijn camera hun portretten vast te leggen vanuit verschillende standpunten. "Wat een **blik** heb je daar zeg!"	Metalen blik, conservenblik/**opslag van ogen, manier van kijken** d/s
29	Cel	Op de universiteit waren ze aandachtig bezig. In het lokaal zaten talloze geïnteresseerden aan verschillende tafels te luisteren naar de gastspreker, die hun voor deze bijzondere gelegenheid iets nieuws ging laten zien. "Laten we deze **cel** eens bekijken."	Gevangeniscel/**biologische cel uit lichaam** d/s
30	Baan	Marie wilde altijd al piloot worden. Ze was nu eindelijk zover. Ze moest alleen nog een test op een groot vliegveld doen. Ze kon niet wachten om trots te vertellen hoe ze alle details uit haar hoofd wist. "Dat is een goede **baan**."	**Beroep**/richting, weg s/d

Appendix C. Small World of Words distributions (in Dutch)

Homonym	Dominant meanings	%	Subordinate meanings	%	Other meanings	%
Licht	lamp, zon, donker, helder, geel, fel, raam, schakelaar, hemel, buiten	80,8%	zwaar, veer	9,1%	dag, klaar, elektriciteit, warm	10,1%
Scheiding	huwelijk, ouders, kinderen, verdriet, pijn, ruzie, pijnlijk, echtscheiding, koppel, relatie, kind, man, vrouw, zorgen	81,8%	haar, grens, splitsing	16,1%	tafel	2,1%
Schaal	fruit, kom, fruitschaal, glas, eten, zilver, bord, tafel	59,1%	aardbeving, weegschaal, wegen, kaart, meter, landkaart, wiskunde	21,3%	ei, kerk, decoratie, eieren	19,6%
Toets	test, examen, punten, school, proef, leren, stress, studeren, moeilijk, cijfer	67,1%	computer, knop, pc, telefoon	12,3%	piano, klavier, muziek	20,6%
Toast	brood, kaas, broodrooster, ontbijt, krokant, eten, boter, lekker, confituur, warm, bruin, hard, boterham, rooster, ochtend	93,7%	champagne	4,1%	droog	2,3%
Gerecht	eten, lekker, koken, restaurant, maaltijd, keuken, recept, warm, pasta, menu, diner, dessert	68,7%	rechter, advocaat, rechtbank, straf, politie, vonnis, rechten	29,3%	gezellig	2,0%
Aangeven	politie, diefstal, misdaad, douane, melden, verraden, geboorte	55,7%	aanreiken, doorgeven, helpen, overhandigen,	23,7%	aanwijzen, belastingen, geven, tonen, richting, aanwijzen	20,6%
Lijn	streep, recht, lat, potlood, wiskunde, figuur, papier,	58,3%	bus	20,0%	dieet, mager, dun, dik, slank, coke, telefoon	21,7%
Stoppen	halt, auto, rood, stilstaan, verkeer, gevaar, verkeerslicht, verkeersbord, remmen	58,5%	ophouden, roken, einde, gedaan, opgeven, doorgaan	36,4%	wachten, pensioen, plots	5,1%
Trap	treden, trede, omhoog, leuning, hout, verdieping, huis, hoog, lift, boven, ladder, tree, steen, kelder, omlaag, lopen	90,0%	schop	3,6%	vallen, vermoeiend, lastig	6,4%
Aas	vissen, worm, vis, gier, hengel, lokken, haak, water, vislijn, jacht, vijver, vangst, prooi, wormen	83,7%	kaarten, kaart, kaartspel, troef	13,8%	dood	2,5%
Blad	papier, schrijven, wit, pen, boek, balpen, examen	55,8%	boom, groen, herfst, bos	42,8%	tijdschrift	1,4%
Hoop	leven, geloof, toekomst, geluk, liefde, moet verwachting, vrede, wanhoop, wens, dromen, verlangen	70,4%	berg, veel, massa, stapel	20,0%	wit, groen	9,6%
Golven	zee, surfen, water, strand, vakantie, sport, zwembad, oceaan, boot, sport, zon, wind, blauw	83,8%	geluid, radio, fysica	10,1%	zon, haar	6,1%
Noot	eten, kraken, boom, walnoot, bruin, hard, lekker, okkernoot, notenkraker, herfst, hazelnoot, vrucht, notenboom, bos	67,4%	muziek, vals, piano, partituur, muzieknoot	31,0%	nood	1,6%

Slot	sleutel, deur, fiets, dicht, sleutelgat, veiligheid, vast	66,4%	einde, toe,	18,6%	kasteel, burcht, sluiten	15,0%
Kussen	slapen, bed, zacht, hoofdkussen, veren, slaap, kussensloop, zetel, sloop	53,5%	zoenen, liefde, lippen, mond, zoen, nat, tong	39,0%	lekker, rood, mals, wit,	7,4%
Vorst	koud, winter, koude, vriezen, kou, sneeuw, ijs, schaatsen, glad	63,2%	koning, kroon, albert, sire, keizer, koninkrijk	36,8%		0,0%
Schat	goud, piraat, geld, kist, piraten, rijk, rijkdom, juwelen, zeerover, kostbaar, koffer	62,1%	lief, liefde, liefste, lieveling, lieverd, partner, kind, geliefde	36,2%	geluk	1,7%
Bank	zitten, park, zetel, rusten, school, tuin, rust, hout	54,5%	geld, sparen, rekening, loket, kluis	45,5%		0,0%
Kraan	water, lekken, lek, wassen, tap, warm, bad, keuken, drinken, badkamer	66,3%	werf, haven, bouw, bouwwerf, hoog, hijskraan, takel	23,6%	vogel, werken, geel	10,2%
Ster	hemel, nacht, maan, licht, zon, heelal, ruimte, geel, kerstmis, planeet, donker, wens, ver, hemellichaam	93,2%	film, beroemd	4,9%	zeester	1,8%
Beeld	tv, foto, televisie, scherm, computer, buis, film, dia	53,9%	kunst, standbeeld, kunstwerk, marmer	34,9%	idee, mooi, tuin, zicht	11,2%
Pad	kikker, groen, vijver, glibberig, vies, amfibie, water, slijmerig, slijm, dier, bruin, traag, kwaken, prins, giftig	87,4%	bos, weg,	8,4%	natuur, sprookje	4,2%
Eng	bang, donker, griezelig, akelig, angstig, halloween, naar, schrik, lift, spook, film, bangelijk	64,0%	smal, nauw	29,9%	benauwd	6,1%
Val	pijn, ongeluk, trap, diep, fiets, ladder, put, grond, parachute, pijnlijk, opstaan, knie, breuk	75,1%	muis, muizen, muizenval, strik	18,5%	bos, bergen, muur	6,5%
Kop	hoofd, dier, staart, haar, paard, voetbal, lichaam, verstand, varken, dieren, slim, pijn	69,8%	koffie, tas, thee, beleg	16,3%	munt, krant, pijn, koppig	13,9%
Blik	cola, conserven, eten, ijzer, metaal, erwten, blikopener, soep, drank, opener, bier, frisdank, roest, drinken, tin	70,4%	ogen, kijken, oog, glimlach	26,8%	grijs	2,7%
Cel	gevangenis, tralies, misdaad, gevangene, opgesloten, gevangen, crimineel, cipier, dief, straf, koud, gevang, misdadiger, metaal,	79,4%	biologie, lichaam, eicel,	14,8%	klein, klooster, nor	5,9%
Baan	*weg, auto, straat, verkeer, rijden*	*43,5%*	*werk, job, geld, loon*	*56,5%*		*0,0%*

Last question had wrong context, so the here stated dominant and subordinare identifier were switched.

Appendix D. Consent form (in Dutch)

TOESTEMMINGSVERKLARING*
voor deelname aan het wetenschappelijk onderzoek:
Taalonderzoek voor studie KI, Radboud Universiteit Nijmegen,
door Nout van Deijck (onder begeleiding van Pashiera Barkhuysen en Franc Grootjen)

- Ik ben naar tevredenheid over het onderzoek geïnformeerd. Ik heb de (schriftelijke) informatie goed gelezen. Ik ben in de gelegenheid gesteld om vragen over het onderzoek te stellen. Mijn vragen zijn naar tevredenheid beantwoord. Ik heb goed over deelname aan het onderzoek kunnen nadenken. Ik heb het recht mijn toestemming op ieder moment weer in te trekken zonder dat ik daarvoor een reden behoef op te geven.

- Ik stem toe met deelname aan het onderzoek.

Naam :
Geboortedatum :

Handtekening :
Datum:

- Ondergetekende verklaart dat de hierboven genoemde persoon zowel schriftelijk als mondeling over het bovenvermelde onderzoek geïnformeerd is. Hij/zij verklaart tevens dat een voortijdige beëindiging van de deelname door bovengenoemde persoon, voor haar/hem, verder geen gevolgen heeft.
Ook zal alle persoonlijke, en ingevulde informatie lopende het experiment, vertrouwelijk behandeld worden, veilig worden opgeslagen, en niet worden gedeeld met mensen buiten het onderzoek. Na afronding van het onderzoek zal alle verkregen data voor hooguit 5 jaar bewaard worden.
Naam :
Functie :

Handtekening : Datum:

** Dit formulier is bestemd voor onderzoek met personen van 18 jaar en ouder die wilsbekwaam zijn. Bij dit soort onderzoek moet door de betrokkenen zelf toestemming worden verleend.*