Relativity of the mind: the mental representation of time as a function of space

Bachelor thesis

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ABSTRACT

In this paper, we investigated whether the mental representation of the abstract concept of *time* is based on the more concrete notion of *space*, following the conceptual metaphor theory by Lakoff and Johnson (1980). This was done using a semantic relatedness task, where both physical and temporal distance between the words, denoting moments in time, were manipulated. Contrary to what was hypothesised, no interaction effect between physical and temporal distance was found. The effects of distance in time and trial type that were found indicate possible flaws in the design of the experiment. Solutions to these problems are proposed. An alternative explanation for the absence of an interaction effect is discussed, and suggestions for further research are made.

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INTRODUCTION

A fundamental basis of reasoning and language comprehension is the mental representation of concepts. This representation is the internal imagination of things that are not necessarily perceived by our senses at that time. For example, it is possible to think about an apple without actually seeing, touching, tasting or smelling one. Similarly, the sentence ‘She eats an apple’ can be understood without seeing someone eating an apple, because we have conceptual knowledge of the words in that sentence and what they stand for in the world. An important question in cognitive sciences is how these representations come to be, and what they consist of exactly.

The representation of concepts: Grounded cognition

One theory that aims to explain how we form mental representations is the framework of *grounded cognition.* This theory proposes that the mental representation of concepts is based on the body and its interactions with the outside world (Pecher & Zwaan, 2005). Thinking involves the activation of the sensory-motor system in the brain, resulting in mental simulation. Thinking about an object activates perceptual information, such as the shape and feel of the object, and action information, for instance the motion that is associated with it (Borghi, 2004; Pecher, Boot & van Dantzig, 2011; Tucker & Ellis, 2004; Zwaan, Stanfield & Yaxley, 2002). For example, thinking about that same apple activates information about its round shape, its smooth surface -as opposed to that of a peach-, how it feels to take a bite out of it or to hold it in your hand. The grounded cognition view rejects the more traditional view that cognition is solely based on manipulations of fully abstract and formal symbols, that are unrelated to the body or somatosensory brain regions (Gallese & Lakoff, 2005). In contrast, the grounded framework states that the brain does not simply perform computations on arbitrary, amodal symbols, but uses mental simulations, bodily states and situated action to support the whole range of cognitive activities (Barsalou, 2008), such as language comprehension.

Several studies showed that language comprehension is based on interactions and perceptual experience the listener or reader has with the environment. For example, Zwaan and Yaxley (2003) presented participants with word pairs, one word above the other, in the order these words typically appear in our environment (*attic* above *basement*) or in the inverse order (*basement* above *attic*). Participants were faster to respond in a semantic relatedness judgment task to word pairs in their iconic order than in the opposite order. This effect was not caused by the order in which the words were read, as the effect disappeared when the words were presented horizontally. These results show that spatial information is activated automatically, and that similarity between the spatial arrangement of words and that of the concepts they denote influences semantic judgment. Similar results were found by Borghi, Glenberg and Kaschak (2004) in a part verification procedure. Participants were presented with a sentence describing an object and then with a probe word. The task was to determine whether this probe word denoted a part of the object described in the sentence. A positive response required either an upward or downward hand movement. Participants showed slower reaction times when the direction of the movement to the response button did not correspond with the direction of the part, e.g. a downward movement to 'roof of the car' and an upward motion to 'wheels of the car'. This 'action compatibility effect' (ACE) shows that not only spatial information but also action information is automatically accessed during language processing. Similarly, Lachmair, Dudschig, De Filippis, de la Vega and Kaup (2011) found that participants that were presented with nouns associated with an up or down location (e.g.

roof or *root*) in a lexical decision task, were faster to react when the response required a compatible upward or downward motion.

These studies suggest that location and action information is automatically activated during language processing. According to theories of grounded language processing, these types of information are part of experiential traces: traces of experience that are formed in the brain by interactions with the world (Zwaan & Madden, 2005). Theses traces are similar to the perceptual or action processes that constructed them, so they can consist of information of all the senses and motion or action information (Barsalou, 1999). When reading or hearing words, experiential traces linked to the denoted concepts are reactivated. So in the studies described above, when reading words during an experiment, participants automatically activated information regarding their previous experience with the concept denoted by that word, in this case information about the typical location of that concept (up or down) and the related action. This knowledge was not only activated, but could influence performance on unrelated tasks: spatial arrangement or required movement compatible with the described objects yielded faster responses than incompatible conditions.

The representation of abstract concepts: conceptual metaphor theory

Experiential traces could provide us with an explanation of how concrete concepts are stored in the brain. But how does this work for abstract concepts? Abstract concepts, such as democracy, honesty and time, are things that do not have a solid form. We cannot experience these concepts through our senses. Since we have never had any perceptual or action experience with such abstract notions, it would be difficult to imagine an experiential trace being formed that consists of information of our senses and motor system. The absence of perceivable information results in the fact that different people have more diverse representations of abstract concepts than of concrete concepts.. The mental representation of such concepts could be based on more basic underlying representations that do result from physical experience (Lakoff & Johnson, 1980). Understanding and thinking about abstract notions could take place by connecting these notions to things that we are more familiar with, using metaphors. The idea that abstract concepts are mentally represented by metaphors was brought forward by Lakoff and Johnson (1980) and their conceptual metaphor theory. According to this theory, our whole conceptual system is metaphorical in nature. Metaphors are not merely a linguistic phenomenon, but a way to ground abstract concepts by linking them to more concrete, more experience-based notions.

There is evidence that people's understanding of abstract concepts is indeed built on their knowledge of other, more physical concepts. Schubert (2005) showed that the concept of power is represented on a perceptual vertical scale when examining the POWER IS UP metaphor described by Lakoff and Johnson (1980). Participants' power judgment of a group was influenced by the spatial position of that group: when asked to find the member of the more powerful group, responses were faster when that group member was presented at the top of the screen, whereas identifying a powerless group was facilitated by presenting it on the bottom of the screen (e.g. 'king' was identified faster at the top, 'servant' at the bottom). Also, identification of a powerful or powerless group was easier when motor responses corresponded with the metaphorical vertical position of that group. Judgments of a powerful group were faster when the up-arrow had to be used than when the down-arrow had to be used. Similarly, Meier and Robinson (2004) showed that participants were quicker to evaluate positive words when they were presented in an up position. Conversely, negative words were evaluated more quickly in the down position. These results are congruent with the GOOD IS UP metaphor (Lakoff & Johnson, 1980). Meier and colleagues (2007) showed a similar effect when they examined the metaphor DIVINITY IS UP. God-like pictures were identified faster in an up position than in a down position. Also, a memory task showed that participants had better memory for the vertical positions of God and Devil-like pictures when these were presented in a position congruent with the metaphor (God at a higher position, Devil at a lower position). Finally, Boot and Pecher (2010) investigated the SIMILARITY IS CLOSENESS metaphor, where they presented two coloured squares at varied distances from each other and asked the participants if they were similar or dissimilar in colour. They found that performance with similar colours was better at shorter distances, whereas performance with dissimilar colours was better at longer distances. The same metaphor was investigated by Casasanto (2008), where he found the same effect for words that denoted abstract entities: these word pairs were judged to be more similar in meaning when presented at shorter distances than at longer distances.

The TIME AS SPACE metaphor

The studies mentioned above investigated the mental representation of the abstract concepts of power, affect (good or bad), divinity and similarity. In the present study the concept of *time* is investigated in relation with the concrete concept of *space*, as seen in the metaphor TIME AS SPACE, described by Lakoff and Johnson (1980). Time and space are two concepts that are closely linked in the physical world. As Einstein's theory of relativity describes, space and time should be considered together and in relation to each other to keep the speed of light constant for all observers. This property of space and time might not only be interesting for physicists, but also for observers of the human mind. Space and time seem to be closely related not only physically, but also in our minds. The link between these two concepts is visible in everyday speech, as illustrated in Table 1 on the next page. Earlier studies suggest

Table 1
Using space to talk about time

Time	Space
It takes a *long* time	It's a very *long* street
Summer is getting *close*	That is *close* to my house
I'm looking *forward* to tomorrow	She moved the car *forward*

that people use space to think about time (DeLong, 1981; Boroditsky, 2000; Boroditsky & Ramscar, 2002; Lai & Boroditsky, 2013). DeLong (1981) found that scaling an environment that was being observed has an influence on the experience of temporal duration. The compression of the experience of duration was relative to the compression of size in the observed environment. Boroditsky (2000) investigated the two possible spatial metaphors in English to sequence events in time: the ego-moving frame and the time-moving frame. In the first frame, you move along a stationary time line: 'we are coming up on Christmas'. In the second, a timeline is seen as a river, on which events move from the future to the present: 'Christmas is coming up'. Boroditsky found that it was possible to use spatial information to prime participants to reason about time in either the ego-moving or time-moving way. Similarly, people more often adopted an ego-moving frame when they had already moved forward to the front of a lunch line than when they were still at the back of the line. This effect was also found in people who had just travelled by plane or were waiting to depart, in comparison to those who were just at the airport to pick someone up. This effect shows that even only thinking about moving through space -and not necessarily doing so- can affect the way someone thinks about time (Boroditsky & Ramscar, 2002). In a study with speakers of English and Mandarin Chinese, Lai and Boroditsky (2013) examined whether experience with spatio-temporal metaphors can influence people's representation of time. Speakers of Mandarin Chinese were less likely to take on an ego-moving perspective than speakers of English, as was predicted by linguistic data comparing the two languages. This effect also occurred when Mandarin speakers were tested in English, which suggests that metaphors can have a chronic effect on mental representation, even when speaking a different language.

Moreover, there is evidence from neuropsychological and transcranial magnetic stimulation (TMS) studies suggesting that space and time are not only closely linked in mental representation, but also in the brain. Specifically, the posterior parietal cortex has been suggested as the area that is responsible for spatial-temporal interaction (Oliveri et. al., 2009).

These findings indicate that space can indeed function as source domain for our understanding of time, and that manipulation in the spatial domain can influence temporal representation. This study aims to investigate whether the manipulation of distance between words that denote temporal concepts (e.g. days of the week) can affect performance during a semantic relatedness task. This type of task requires semantic, deep processing, which ensures that participants access the meaning of the word. Earlier research fits with the prediction that irrelevant spatial information, in this case the physical distance between two words, can influence the processing of temporal concepts. This influence could be visible in reaction time and accuracy. Expected is that word pairs that are close in time (e.g. Monday-Tuesday) are identified as semantically related faster when presented close to each other than when presented further apart, whereas word pairs that are more distant in time (e.g. Monday-Friday) are identified faster when presented further apart than when presented close to each other. Also, a discrepancy between distance in time and physical distance could result in a higher error rate. To examine whether spatial distance can affect the processing of abstract notions of time, a test was designed based on the experiment by Boot and Pecher (2010) on the metaphor SIMILARITY IS CLOSENESS.

METHOD

Participants

A total of 43 participants (11 males and 32 females, mean age = 22, SD = 2,8), recruited on social media, took part in the experiment via the online survey tool Qualtrics. They received no monetary compensation for participating. To participate, respondents had to be between the ages of 18-35 years old, not suffer from dyslexia and speak Dutch as native language.

Design and procedure

Word pairs were chosen in such a manner that they either denoted two moments on a timescale that were, metaphorically speaking, close to each other or far away from each other in time (e.g. Monday-Tuesday or Monday-Friday). Each pair was presented two times on a computer screen, once with 1 cm distance between the words (the close-condition) and once with 4 cm distance between the words (the distant-condition). Participants were instructed to take part on a laptop or pc, not on a smartphone, which was verified later on. Reaction times were measured on a semantic relatedness judgment task. Participants were instructed to choose whether or not the two presented words were semantically related (‘m’ key) or not (‘c’ key). Six near-test pairs (e.g. Monday-Tuesday) and six far-test pairs (e.g. Monday-Friday) were used as well as twelve additional filler pairs, distributed in two groups of semantically related words. The filler words too, were abstract in nature. All test items are listed in the appendix.

Table 2
Trial types with examples

	Semantically related	Semantically unrelated
Experimental – Experimental	Monday-Tuesday	
Experimental – Filler		Monday-Jealous
Filler - Filler	Jealous-Stubborn	Jealous-Diameter

This design resulted in 2 x 4 x 12 = 96 trials. Position of the words within a word pair was not manipulated (e.g., Monday-Tuesday and Tuesday-Monday) because participants may or may not consider the normal order of the days of the week or months of the year. For example, Tuesday-Monday are six days apart if you count forwards, but only one day if you allow backwards counting. To avoid confusion, only one word order of each pair was tested. A fixation cross in the centre of the screen was presented during 1000 milliseconds before each trial, and between trials a blank screen was shown for 1500 milliseconds. Both words were presented simultaneously and appeared vertically centred. Before starting the experiment, participants were presented with 12 word pairs for training. Afterwards, they were asked to answer questions about their age, gender, native language, whether or not they had dyslexia, how difficult they found the experiment and if they could guess the purpose of the study.

RESULTS

Date of five participants were excluded from the analysis. One guessed the purpose of the experiment, one was not a native speaker of Dutch, one did not fit the age restrictions, one switched the response keys, and one participant was excluded because she had an overall accuracy rate of less than 80%.

Using the results of the remaining 38 participants, an analysis of the reaction times was carried out. Of the correct answers, reaction times more than three standard deviations

Table 3
Mean reaction times and mean error rates

Screen distance	Reaction times		Error rates	
	Close in time	Distant in time	Close in time	Distant in time
Close	846 (207)	896 (243)	0,88 (3,8)	3,07 (6,5)
Distant	872 (169)	933 (234)	1,32 (6,0)	0,88 (3,8)

Note: reaction times are in ms, error rates in %. Standard deviations are shows in brackets.

from the participant's mean were excluded from further analysis. Deviant slow reaction times were assumed to be the result of a loss of concentration during the task. This resulted in removal of 1,64% of all correct responses. Planned was to exclude all reaction times <550 ms, following Zwaan and Yaxley (2003) with a similar task, but a few participants were both very fast and accurate. Thus, very fast responses were only excluded if reaction times were more than three standard deviations below the mean. We presumed that such fast reaction times would be the result of impatience with the repetitive task, rather than a genuinely fast decision.

First, the effects of distance on the screen, distance in time and their interaction were analysed. A two (close on screen vs. distant on screen) by two (close in time vs. distant in time) repeated measures ANOVA was performed on the remaining reaction times of correct answers on the experimental trials. Mean reaction times are given in Table 3. The analysis showed a significant effect of distance in time ($F\ (1, 37) = 11{,}8,\ p = 0{,}001,\ \eta_p^2 = 0{,}24$), which means that days and months close to each other in time (e.g. Monday – Tuesday) were recognized as related faster than those further apart in time (e.g. Monday – Friday). There was no significant effect of distance on the screen ($F\ (1, 37) = 2{,}9,\ p = 0{,}096$) and no significant interaction between distance on the screen and distance in time ($F < 1$).

Then, a two (experimental vs. filler) by two (close on screen vs. distant on screen) repeated measures ANOVA was performed on the reaction times of the semantically related trials, both experimental and filler. Experimental items were faster to be recognised as related than the filler items ($F\ (1, 37)= 98{,}5,\ p < 0{,}001,\ \eta_p^2 = 0{,}73$). Again, no significant effect of the distance on the screen was found (*F < 1).* Also, the analysis did not reveal an interaction effect between trial types and distance on the screen (*F < 1).*

Additionally, a comparison was made between related vs. unrelated word pairs and screen distance on the reaction times on all trials, again using a 2x2 repeated measures ANOVA. This revealed that responses were faster on related word pairs than unrelated word pairs ($F\ (1, 37) = 12{,}0$, $p = 0{,}001$, $\eta_p^2 = 0{,}25$). Here, an effect of distance on the screen was found ($F\ (1, 37) = 6{,}2$, $p = 0{,}018$, $\eta_p^2 = 0{,}14$). Word pairs presented with a small distance between the words yielded faster responses than word pairs that were presented further apart. There was no interaction effect ($F > 1$).

Finally, a two (close on screen vs. distant on screen) by two (close in time vs. distant in time) repeated measured ANOVA was performed on the error rates on the experimental items. Mean error rates are shown in table 3. No significant interaction effect was found between distance in time and distance on the screen ($F\ (1, 37)=2{,}785$, $p = 0{,}110$). No effect of distance in time was found (Monday-Tuesday vs. Monday-Friday) ($F\ (1, 37) = 2{,}792$, $p = 0{,}103$), nor was there an effect of distance on the screen in the error rates ($F\ (1,37) = 1{,}147$, $p = 0{,}291$). Note that very few errors were made in the experimental trials.

DISCUSSION AND CONCLUSION

Word pairs that were close in time (e.g. September-October) yielded faster responses than word pairs distant in time (e.g. December-June). Participants were quicker to identify two words as semantically related when the two days or months presented were consecutive in time. This is probably due to a priming effect: the first word of the pair presumably primed for the word that denoted the consecutive day or month, but not for words denoting other days or months. Words denoting two consecutive days are most likely more often found together in the world than words denoting two arbitrary days. To eliminate this priming effect, a possibility would be to choose word pairs that denote moments in time that do not directly follow each other. This could work with the months of the year, but the difference between the ‘close in time’ and ‘distant in time’ conditions using days of the week might become too small, since there are only seven days in a week. For further research, choosing other word pairs might increase the chances of finding the hypothesised effects. Without the priming effect, it would become more likely to find effects based on the actual distance in time between two denoted moments instead of finding a more or less automatically triggered faster response due to priming.

Participants recognised the experimental word pairs faster than the semantically related filler pairs. This shows that the chosen filler categories (character traits and geometrical terms) were semantically less clearly coherent than the experimental categories of days and months. Also, the category ‘character traits’ contained both positive and negative traits, such as respectively kind and jealous. It is possible that it felt contradictory to participants to judge a positive and negative trait as related, because they are opposed in the sense that one trait is generally viewed as good, the other as bad. This contradiction could have led to longer reaction times. The difference in difficulty between experimental and filler trials could have been noted unconsciously by the participants, leading them to guess that both groups served a different purpose. Further research might benefit from choosing abstract filler items that are more coherent and as easily recognised as related as the experimental items.

The result that related word pairs were recognized faster than unrelated word pairs was expected, based on earlier research with similar tasks (Boot & Pecher, 2010; Zwaan & Yaxley, 2003). This effect is not relevant for a possible interaction between distance in time and in space of the experimental items, because all experimental trials were semantically related.

Reaction times were slower overall in the ‘distant on screen’ condition than in the ‘close on screen’ condition. It is possible that participants took longer to respond to word pairs in the ‘far on screen’ condition because reading both words required making a saccade, an eye movement. This is hard to verify, as participants did the task on their own computers. This means the distance between them and the computer screen varied, which makes it impossible to calculate the visual angle between both words and compare it to the visual angle of circa 5° that is processed by the fovea. (Millodot, 2014). Boot and Pecher (2010) found an effect for distance in their study about the SIMILARITY IS CLOSENESS metaphor, and also an interaction effect between similarity (the same or a different colour) and distance. The same distances were used in their study as in the present study, but the size of their stimuli were constant. The words used here were not all of the same length, so the total distance between the first letter of the first word and the last letter of the last word varied between trials. To control for eye movement, all participants would have to do the task on the same computer screen, sitting on a chair at a fixed distance. Eye-tracking techniques could be used to see whether participants still move their eyes to read the word in the ‘distant on screen’ condition.

Conceptual metaphor theory proposes that we mentally represent abstract concepts by linking them to concrete concepts. However, the link between the abstract notion of time and the more physically concrete notion of space, visible in metaphorical language, was not found in the present study. Naturally, this does not mean that conceptual metaphor theory is false, as there is ample experimental evidence that we do use concrete source domains to think about abstract target domains (e.g. Boroditsky, 2002; Casasanto, 2008; Meier & Robinson, 2004; Schubert, 2005). Evidently, a lack of statistical power could account for the absence of an effect. To obtain more reliable data, more participants would have to take part (Peck & Devore, 2011).

Based on the grounded cognition framework and earlier research using similar methods, the assumption was made that language processing involves the activation of experiential traces or mental simulation. Specifically, word reading activates spatial information about the denoted concepts, even when this is irrelevant for the task. This spatial information can in turn interfere with or facilitate the task. This holds for concrete objects, as was shown by Zwaan and Yaxley (2003) among others. Word pairs were recognised as semantically related more quickly when they were shown in their typical spatial order, e.g. NOSE above MOUTH. This spatial information can also be metaphorical in nature, as was shown in a study by Schubert (2005) about the POWER IS UP metaphor. When presented with a word pair denoting a powerful and a powerless person and asked to indicate which person was the powerful one, reaction times were shorter when the powerful person was presented above the powerless person. Thinking about power automatically activated a vertical scheme.

But what is important to note, is that the participants were *asked* to think about the relation between both words in terms of power, which in turn triggered a vertical scheme. This is different than in the study by Zwaan and Yaxley (2003), because here the participants *automatically* activated spatial information concerning the relation between both words, with one typically being in a higher position than the other. So Schubert's study does not show that the metaphorical relation between two words *automatically* activates spatial information, it shows that spatial information is activated *when asked to think about* the metaphorical relation between two words. In short, there is an extra step in the process:

1) NOSE above MOUTH → spatial information activated → facilitated response

2) MASTER above SERVANT → *think about their relationship in terms of power* → spatial information activated → facilitated response

This extra step, explicitly asking about the abstract concept of interest, is used in other studies investigating conceptual metaphor using similar tasks (Casasanto, 2008; Meier & Robinson, 2004; Zanolie et. al., 2012), but not in the present study. Recall that participants were only asked to judge whether two presented words were semantically related or not. There was no explicit question forcing the participants to think about the two words and their relation in terms of time, in turn activating information about space. Instead, the expected interaction effect between distance in time and distance in space was based on the *automatic* activation of spatial information, as was seen in experiments with physical, concrete spatial relations. As this effect was not found, it seems that the processing of word pairs that are related in a more abstract way, such as the days of the week, works differently. The automatic mental simulation that takes place during processing of concrete words, does not seem to take place for abstract notions and their source domain unless prompted. So, when processing words pairs such as NOSE-MOUTH, we automatically picture what those two things look like and how they physically relate to each other. Conversely, when processing word pairs such as MONDAY-FRIDAY, it is difficult to imagine what one would picture. Days of the week do not have a solid form, no direct image comes to mind. But when asked about the time difference between the two words, the metaphor with space comes in play. Only then spatial information is activated, information that could interfere with or facilitate the response in an experiment. So, it is possible that participants did not consider the distance in time between the experimental word pairs at all, simply because they were not prompted to do so. A logical suggestion for further research would be to change the task in such a way that participants are forced to think about time distance, and then see if that activates information about physical distance.

In conclusion, this study on the mental representation of time and its relation with space showed no interaction effect between temporal and physical distance. Although these results do not support the conceptual metaphor theory, it seems that the explanation for the absence of an effect is most likely found in the design of this study. It is, in any case, too soon to reject the idea that the abstract notion of *time* is mentally represented by linking it to more the concrete concept of *space*.

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APPENDIX

Test items

Experimental – experimental related	Filler - filler related	Experimental - filler unrelated	Filler - filler unrelated
januari - februari	aardig – spontaan	aardig – januari	spontaan – hoogte
juli - augustus	jaloers – grappig	juli - grappig	inhoud – grappig
september – oktober	koppig – slordig	jaloers – juni	koppig – lengte
februari - augustus	spontaan – jaloers	maandag – spontaan	breedte – slordig
april – oktober	grappig - koppig	slordig – woensdag	jaloers – diepte
december – juni	slordig – aardig	zaterdag – koppig	omtrek – aardig
maandag – dinsdag	lengte – hoogte	november – lengte	lengte – spontaan
woensdag – donderdag	breedte – diepte	breedte – december	grappig – omtrek
vrijdag – zaterdag	omtrek – inhoud	februari – omtrek	diepte – koppig
maandag – vrijdag	inhoud – hoogte	diepte – vrijdag	aardig – breedte
woensdag - zondag	diepte – lengte	zondag – hoogte	hoogte – jaloers
vrijdag – dinsdag	breedte - omtrek	inhoud - dinsdag	slordig - inhoud

Note: Of the experimental trials in the left column, the light grey cells indicate ‘distant in time’ word pairs, the unshaded columns indicate ‘close in time’ word pairs.