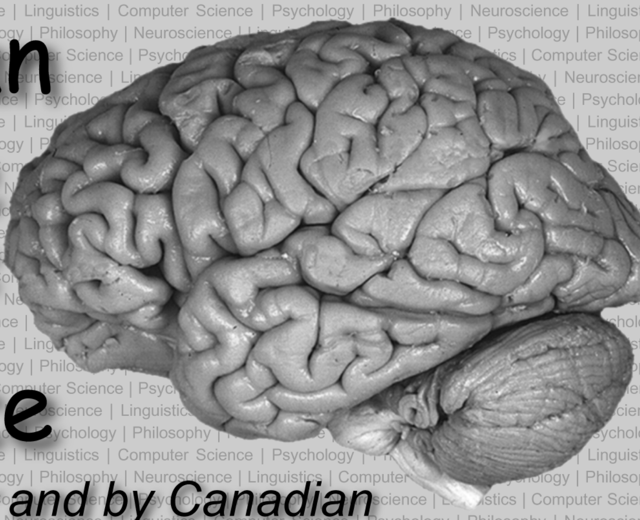
Canadian Undergraduate Journal of Cognitive Science



A refereed journal for and by Canadian undergraduates interested in cognitive science-related topics.

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Spring 2002 Issue

IN THIS ISSUE:

Executive Editor: Chris Mathieson
Associate Editors: Jeremy Holman & Kimberly Voll | **Referee Coordinator:** Sam Scott
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Canadian Undergraduate Journal of Cognitive Science

The Canadian Undergraduate Journal of Cognitive Science is an electronic journal published by the Cognitive Science Student Association at Simon Fraser University. Our aim is to provide a forum for students to share work amongst peers and gain valuable experience in the process of getting an academic paper published. As a publication, CUJCS will provide a unique reference for students, showcasing research by other undergraduate students, improving the contact and exchange of ideas between Canadian students and cognitive scientists alike, and illustrating the interdisciplinary work that is the hallmark of cognitive science everywhere.

Although preference will be given to Canadian students, contributions from students elsewhere are strongly encouraged.

Copyright Information

In keeping with the editorial policy of another cognitive science journal, "Connexions", we are of the opinion that papers submitted to our journal will usually be samples of work-in-progress. As such, acceptance in CUJCS should not impede publication of a later version in traditional journals.

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Undergraduate students interested in contributing a paper to CUJCS should contact the Editors at cogsci-journal@sfu.ca for up-to-date submission details.

The Editors also appreciate any offers by graduate students or faculty in cogsci-related disciplines for refereeing.

Staff

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INTRODUCTION

It is with great pleasure (and relief) that we introduce the Canadian Undergraduate Journal of Cognitive Science (CUJCS). The purpose of the journal is to provide a forum for students to share work amongst peers and gain valuable experience in the process of getting an academic paper published. As a publication, CUJCS will provide a unique reference for students, showcasing research by other undergraduate students, improving the contact and exchange of ideas between Canadian students and cognitive scientists alike, and illustrating the interdisciplinary work that is the hallmark of cognitive science everywhere.

We would like to thank everyone who submitted essays and helped make this inaugural year of CUJCS a success. In selecting papers for publication, we looked for work that exemplified the characteristics of a good undergraduate paper, such as clarity of presentation and coherent argument. In addition, we looked for work that crossed traditional academic boundaries in interesting ways. The four papers published here more than meet these criteria.

As this effort was a first for most of us involved, the conception, gestation and delivery of this issue was not without its challenges. Although we are pleased with our final product, we are conscious that there is room for improvement in future editions of this journal. First, since this is supposed to be a national journal, every effort will be made to accommodate French submissions in future issues. We would like the journal to be more representative of the diverse cognitive science programs across Canada.

In addition, we hope to make the journal a truly Canadian effort, not only in its content but also in its production. To this end, we hope to expand our editorial process to include individuals and student organizations from other universities to take better advantage of the different perspectives, expertise and resources available. By way of this last point, if you are interested in reading for next year's journal, please contact us by email. Please also visit the CUJCS website regularly for updates on deadlines and submission guidelines for future issues.

We would like to thank those people without whom this effort would not have been possible. We appreciate the assistance of faculty and students at other universities who disseminated our Call for Papers and encouraged submissions within their respective departments; Dr. Nancy Hedberg and Dr. Rodger Blackman, our faculty advisors, for supporting this project from the beginning and providing wise words of advice; Andrew Brook; our fellow members of the Simon Fraser University Cognitive Science Student Association, for all their support; the organizing committee at Carleton University of PHICS 2001 (a graduate student conference in Philosophy and Cognitive Science) for the evening recreation time wherein this journal was first conceived.

A unique and considerable debt of thanks is owed to Sam Scott, who was not only an exemplary Referee Coordinator but also an indispensable source of guidance through the technical aspects of founding a journal.

Finally, we welcome all feedback, comments and suggestions that will help is improve this journal. We hope you find CUJCS a thought provoking and informative read and we look forward to promoting the diversity in Canadian undergraduate cognitive science for years to come in the Journal's pages.

Chris Mathieson
Kimberly Voll
Jeremy Holman.

EFFECT OF GRAMMATICAL CATEGORIES AND SEMANTIC RELATEDNESS ON IMMEDIATE WORD PAIRS RECALL

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ABSTRACT

Huttenlocher and Lui (1979) found that semantic relatedness affected the short-term memory for both concrete nouns and verbs but the effect for nouns was stronger than the one for verbs, suggesting that there is an organizational difference between these two word categories. The present study expanded this line of research, investigating the effect of semantic relatedness on recall in combination with nouns and verbs not only as separate categories but also as interacting mental constructs. 25 university students were presented with lists of semantically related and unrelated verb-verb, noun-noun and verb-noun pairs and were asked to remember and later recall as many of the pairs as possible. The results confirmed the hypothesis that nouns are recalled better than verbs and that semantic relatedness facilitates memory, but they were inconsistent with the prediction that semantic relatedness affects more noun pairs than verb pairs. The main effects of word category and semantic relatedness were significant but there was no significant interaction between these two variables. Organizational theories of nouns and verbs as well as other theories of the verb/noun distinctions were considered as possible explanations of the results.

INTRODUCTION

Many studies have suggested that the grammatical class of words is an important dimension of lexical organization. The major grammatical categories are nouns, verbs, adjectives, adverbs and prepositions. Words from different categories not only convey different meanings but they also carry other distinctive characteristics such as "strength of imagery, distribution and frequency of occurrence" (Sommers, 1998, p. 187). Verbs and nouns are two categories, which have been extensively investigated in connection to these characteristics.

Evidence has been found that there is a neuroanatomical distinction between the processing of nouns and verbs (Daniele, Giustolisi, Silveri, Colosimo, et al., 1994). These findings suggest that the temporal lobe of the left hemisphere of the brain might be significantly involved with the processing of nouns while the frontal lobe of this hemisphere might play a crucial role in the processing of verbs.

Furthermore, a particularly strong distinction is made between the mental organization of concrete nouns and verbs. These organizational patterns are reflected in people's memory for semantically related nouns and semantically related verbs versus semantically unrelated nouns and verbs.

Huttenlocher and Lui (1979) tested this proposition and found that semantic relatedness affected the short-term memory for both concrete nouns and verbs but the effect for nouns was stronger than the one for verbs, suggesting that there is an organizational difference between these two word categories. The relation of this difference to age was also investigated. Both adults and children showed the same patterns of results - semantic relatedness affected the recall of nouns more than the recall of verbs.

One theory explains these findings with the distinctive lexical organization of verbs and nouns: nouns are hierarchically organized in domains whereas verbs have a matrix-like organization (Huttenlocher & Lui, 1979). The main difference between these two types of organization is the strength of association between the words in the structure. Nouns, being in multilevel hierarchies, are very closely related to each other because the meaning, denoted by a noun in one level of a hierarchy, is carried by nouns on lower levels of the same hierarchy. On the other hand, verbs denote actions or states and often require objects. Thus, the relation among verbs is much more loose than the one among nouns, and verbs are much more closely related to their objects than they are to other verbs.

The present experiment was designed to extend this line of research, addressing new aspects of the noun-verb organizational differences. Focusing beyond the major categorical distinction between nouns and verbs, this study investigated the relations between specific subcategories of nouns and verbs, that is action verbs and concrete nouns. The subcategory of action verbs has particular properties which tie it closely with the subcategory of concrete nouns, namely the fact that most action verbs require objects. This requirement forces a tight association between a verb and a noun. The strength of this association was to be tested against the one between noun and noun, and verb and verb.

If the strength of association between two words is reflected in the short-term memory for this pair of words, and if most verbs require objects, then people should be more likely to recall verb-noun (V-N) pairs rather than noun-noun (N-N) and verb-verb (V-V) pairs, regardless of the presence or absence of semantic relatedness. Furthermore, if the organization of nouns exhibits more structural coherence than the one of verbs, then N-N pairs should be recalled better than V-V pairs when there is semantic relatedness between words, but this effect should not be so strong in the absence of semantic relatedness.

Semantic relatedness between two nouns, two verbs or a verb and a noun was operationally defined in two ways: first, as synonymy, and second, as complementation. Two verbs/nouns are semantically related if they are synonyms of each other, for example *murder-kill*. Furthermore, two nouns or a noun and a verb are semantically related if the noun is a pragmatically and meaningfully appropriate complement to the verb or to another noun, for example *drive-car* or *mother-father*.

In summary, this study looked at the effect of word categories and semantic relatedness on short-term memory.

METHOD

SUBJECTS

The subjects of this experiment were 25 students enrolled in a second-year research methods psychology course. While participants were informed that this was a memory study investigating short-term memory of pairs of words, they were not given any information regarding the specific variables being manipulated or the hypothesis being tested.

MATERIALS

Six different lists of word pairs were used. Half of these lists consisted of semantically related word pairs, whereas the other half consisted of semantically unrelated word pairs. Three different combinations of the noun and verb categories were investigated: Noun-Noun (N-N), Verb-Verb (V-V), and Verb-Noun (V-N). Therefore, there were semantically related N-N, V-V and V-N lists as well as semantically unrelated N-N, V-V and V-N lists.

The words, which were concrete nouns (operationally defined as nouns that depict entities or objects) and action verbs (i.e. verbs that denote actions), were taken from two lists of frequently occurring English nouns and verbs. These lists were conveniently called Alphabetical

Lists of Concrete Nouns and Action Verbs of High Frequency and are included in Appendix B. They were compiled using four different sources: The use of words in context: The vocabulary of college students (Black, Stratton, Nichols, & Chavez, 1985), Word frequencies of spoken American English (Dahl, 1979), Word frequency book (Carroll, Davies, & Richman, 1971), and a list of high-frequency high-concreteness nouns provided by Dr. B. Whittlesea.

Thirty nouns (randomly divided into three groups of ten) were randomly chosen from the alphabetical list of concrete nouns and thirty verbs (again three groups of ten) were randomly chosen from the alphabetical list of action verbs. The ten words from one of the noun groups were matched with ten other nouns from the alphabetical list of concrete nouns so that they formed the semantically related N-N list. The words from this same noun group were randomly combined with the words from one of the other two noun groups to form the semantically unrelated N-N list. Similarly, the ten words from one of the verb groups were matched with ten other verbs from the alphabetical list of action verbs so that they formed the semantically related V-V list. And this same verb group was randomly combined with one of the other two verb groups to form the semantically unrelated V-V list. Finally, the remaining verb and noun groups were used to form the semantically unrelated V-N list, and the verbs of this list were matched with ten other nouns from the alphabetical list of concrete nouns so that they formed the semantically related V-N list. These six lists are also included in Appendix B.

PROCEDURE

The subjects were tested in two small groups (one of 15 and one of 10 participants) in an open psychology laboratory. A mixed factorial design with combined assignment was used. Semantic relatedness was the independent groups variable and participants were randomly assigned to the two levels of this variable: present or absent. Grammatical categories in word pairs was the repeated measures variable and participants were treated with all levels of this variable: V-V, N-N, and V-N word pairs. Complete counterbalancing for the three levels of this variable was used to avoid order effects. Within each independent group, there were six different orders of the same three levels of the grammatical categories variable.

Participants were given 3 printed lists of 10 word pairs and asked to remember as many of these pairs as possible, without considering their order. They had one minute to memorize each list. After every memorization period, there was a minute-and-a-half free-recall period when participants had to write down the word pairs they remembered. After a 1-minute rest period the same procedure was repeated with the next list.

Participants were instructed about their task (i.e. memorization of word pairs) and the time periods described above. They were also told that the order of the pairs does not make a difference and single words will not be counted, but only correct pairs of words.

The number of correctly recalled word pairs was measured. Minor spelling errors were ignored and pairs, in which the position of the words was switched, were also accepted.

RESULTS

The recall scores of individual subjects are shown in Appendix A. Average scores for the V-N, N-N and V-V word-pair lists, for all subjects and for the two groups (one treated with semantically related (SR) and the other one treated with semantically unrelated (nSR) pairs) separately, are shown in Table 1. These average scores are also shown on Figure 1, where the effect of the two independent variables (grammatical categories and semantic relatedness) on the dependent variable (word pair recall score) is shown graphically. The data was further analyzed using ANOVA test for repeated measures. The results are shown in Table 4.

From Table 1 it will be seen that on average subjects recalled much better V-N and N-N pairs than V-V pairs, regardless of the presence or absence of semantic relatedness. A repeated measures analysis of variance showed this difference to be significant, F = 12.681, p = 0.002.

Furthermore, it is clear from Table 1 and Figure 1 that on average subjects recalled much better word pairs, which were semantically related, than ones, which were not. This pattern applies for all word categories: V-N, N-N and V-V. ANOVA shows also this difference to be significant, F = 29.393, p < 0.001.

Finally, as visible on Figure 1, the effect of semantic relatedness on the recall of the different word categories pairs is almost equal for all categories. The difference between the average scores for the nSR and the SR V-N lists is 1.7, while it is 2.1 for the nSR and SR N-N lists, and it is 2.3 for the nSR and SR V-V lists. The fact that these differences are so similar to each other means that there is not interaction between the two variables. This was confirmed by the nonsignificant outcome of the analysis of variance for the variables interaction, F = .395, p = .676.

DISCUSSION

The results of the present experiment indicated a significant main effect of word categories on word-pair recall, a significant main effect of semantic relatedness on word-pair recall, and no significant interaction between word categories and semantic relatedness.

These results support the hypothesis, which predicted that subjects would recall verb-noun (V-N) pairs and noun-noun (N-N) pairs better than verb-verb (V-V) pairs, regardless of the presence or absence of semantic relatedness, and that the presence of semantic relatedness would facilitate recall. However, V-N pairs were not recalled better than N-N pairs, as was predicted in the hypothesis, and semantic relatedness did not affect N-N word recall more than V-V word recall. Possible explanations of these findings are examined below.

The results of the present experiment are partially consistent and partially inconsistent with the findings of Huttenlocher and Lui (1979). They are consistent with the previous results in that they support the hypothesis that nouns are better recalled than verbs and that semantic relatedness facilitates short-term memory for word lists. However, they are inconsistent with the findings that semantic relatedness effects the short-term memory for nouns more than the one for verbs.

As discussed previously, there is no significant interaction between the two manipulated variables, word categories and semantic relatedness. If there is no interaction between these two variables, then the theory, presented by Huttenlocher and Lui (1979), which distinguishes between nouns and verbs as having different organizational structure, has not been supported by the findings of the present experiment.

The inconsistency between the results of this experiment and the ones of previous studies can be explained by two alternative theories of noun versus verb categorical characteristics as related to memory.

Firstly, it might be that nouns are better associated with each other than verbs are, not because they have a more coherent organizational structure but because they are dominant in everyday speech.

In general, nouns and verbs are much more inflected in speech than other word categories such as adjectives, adverbs and prepositions (Sommers, 1998). Furthermore, the occurrence of nouns is more frequent than the one of verbs, making them easier to remember. The more people encounter a particular class of words, the easier it is to classify these words as belonging to a certain category, to remember them, and to associate them with one another.

Support for this proposition comes from studies like the one of Marx (1979), where subjects were presented with lists of 10 words and asked to associate freely for a minute. 3 of the words on the lists were nouns, 3 were verbs, 3 were adjectives, and the last one belonged to any of these three categories. He found that regardless of the class of the stimulus words (the ones on the list), there was a significant tendency to associate nouns with any of these words. He concluded that nouns were the dominant word category as a carrier of association. His findings support the theory that compared to verbs nouns are more stressed as a word category and are a more dominant mental construct.

This theory is also supported by the results of the present experiment, which show that there is a significant effect of word category on recall: pairs of nouns are much better remembered than pairs of verbs. Furthermore, as shown on Table 1, the average recall for V-N pairs was almost equal to the average recall for N-N pairs. This means that even if there is an organizational difference between the noun and verb categories, there is also a strong association transcending the categories’ boundaries and connecting nouns and verbs with each other. This tendency fits with the suggestion that verbs are much more closely related to their objects than they are to other verbs (Huttenlocher & Lui, 1979). The reason for this might be the dominancy of nouns as a mental construct.

Secondly, nouns may not only be the word category most stressed in speech, but they may also be better imagery-encoded than verbs. When a word denotes an image apart from a verbal meaning, it is easier to remember.

Fletcher, Shallice, Frith, Frackowiak, et al. (1996) examined the effect of imagery and semantic relatedness on retrieval of word pairs and found that the recall of imaginable and nonimaginable words were associated with activity in different areas of the brain. The recall of both types of words was associated with activation of the left dorso-lateral prefrontal cortex while only the recall of imaginable words was additionally associated with activation of the precuneus. These findings support the hypothesis that the imagery-encoding words carry effects word recall.

More importantly, findings supporting Paivio's Dual-Coding Theory (DCT), proposed in 1969, further contribute to viewing the imagery-capacity of concrete nouns as an attribute facilitating recall (Jessen, F. et al., 2000; Sadoski, M., Goetz, E. T. & Avila, E., 1995; Paivio, A., Walsh, M. & Bons, T., 1994). DCT holds that words are remembered in two ways – through verbal encoding and through image encoding. Concrete nouns, which are highly imaginable, are, therefore, more easily remembered than verbs (as well as any other word category). DCT also argues that the effect of concreteness (i.e. imaginability) and the one of semantic relatedness on word recall are independent of each other, which means that no matter whether semantic relatedness in a word pair is present or not, a pair of nouns is more easily remembered due to the concreteness effect.

There is controversial evidence for the superiority of nouns as image-carriers, but if future studies support this theory, then one possible explanation of the results of the present experiment might be that nouns are better recalled than verbs because their image-encoding facilitates short-term memory.

It should be noted that there are a number of limitations and problems of the present study.

Only 25 subjects were tested and this is absolutely unsatisfactory considering the complexity of this experiment. If more subjects were available it might be that the absent interaction between the two variables (grammatical categories and semantic relatedness) was going to surface, and in that case, the results would be fully consistent with the findings of Huttenlocher & Lui (1979).

Additionally, the sources of frequent English verbs and nouns used in the experiment were mostly from the 1970s and 1980s and the English vocabulary surely has changed in the past 20 years. Unfortunately, apart from Whittlesea's current list of high-frequency high-concreteness nouns (obtained through personal communication), no recent sources were available. This might have affected the short-term memory of the subjects (second-year university students) for these words if they did not find them to be part of their everyday vocabulary. Therefore, one possible improvement for this study would be the use of more recent sources of frequent English words.

In summary, the present study has certain limitations connected to sample size and sources of materials, which might have affected the results. Nonetheless, the results show significant consistency with previous findings about the noun/verb categorical distinction.

In order to supplement or perhaps expand the theory of the different organizational patterns of nouns and verbs, further studies might investigate the plausible dominancy of nouns as a word category and mental construct in comparison to verbs as well as other grammatical classes. The potential status of nouns as best imagery-carriers may also be subject of further research in the field of psycholinguistics.

In conclusion, the present experiment presents additional data for the significant distinction between verbs and nouns. Whether this distinction originates in the different organizational structures of these two word categories or in some other differences between nouns and verbs as mental constructs is still to be shown by further investigation.

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MENTAL MODULES AND ESSENTIALISM: TRAIT VARIATION AND ITS IMPLICATIONS FOR EVOLUTIONARY PSYCHOLOGY

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ABSTRACT

Jerome Barkow, Leda Cosmides, and John Tooby in their book, The Adapted Mind, espouse a view of evolutionary psychology. They claim that given homo sapiens evolutionary history; psycology is provided with the means to decypher the "mental modules" that underlie and explain the nature of humanity. Their belief is that with our knowledge of anthropology, biology and genetics we can fully understand the common cognitive structures that are present in every human alive today. I argue the opposite, present views of genetics and variation in the philosophy biology demonstrate why this is not possible. I draw from the views of David Hull, Elliot Sober and Marc Ereshefsky to demonstrate why theories dependent on essentialism within species is a project that is bankrupt and should be given up in favour of projects that can actually lead us to an understanding of human cognition.

Since Charles Darwin’s famous voyage on the HMS Beagle the theory of evolution has had an increasingly prominent role in the development of a number of fields. Among these is the field of psychology. In the last two decades or so, psychologists have been turning more and more to biological theories of adaptation to draw conclusions about the behavior and cognitive faculties of humans. In the forefront of this movement towards adaptation and evolution as a basis of human mentality are theorists such as Jerome Barkow, Leda Cosmides, and John Tooby. In 1992 these three published a book titled *The Adapted Mind* which set the theoretical tone, so to speak, for psychologists who believe that if one wishes to come to an understanding of why humans are they way they are, all that one needs to do is examine the history of the species *homo sapiens* and identify the adaptive pressures which have shaped its development. Despite the heavily influential nature of the views of Barkow, Cosmides, and Tooby there are some worries about the aptness and veracity of their claims; among these, are arguments against essentialism and the concept of normalcy of traits within species that are found in the philosophy of biology.

In the philosophy of biology there is a long running debate about the nature of species. The predominant views involved in this debate are cluster theory, essentialism, and the historical approach (Ereshefsky, 2001). For the purposes of this paper, we will only discuss the issues that arise with essentialism; the simple reason being that they are the most informative in regards to the topic at hand. Recently, however, theorists in the philosophy of biology have been moving away from traditional views of essentialism as it was first proposed by scholars such as Aristotle, and which heavily influenced early biologists such as Linnaeus. Many philosophers, such as Hull, Sober, Rosenberg, Williams, and Ereshefsky (Ereshefsky, 2001) believe that given what we have learned about genetics, evolution, and the variation of traits within species the traditional views of essentialism no longer apply to taxonomy, nor does it apply to the understanding of the phenomes of organisms. This rejection of essentialism has major implications for Barkow et al.

According to Barkow, Cosmides and Tooby (1992), the central premise of their theory is that "beneath variable behavior(s) lie universal mechanisms" (Barkow, Cosmides, & Tooby, 1992). They claim that "there is a universal human nature" (Barkow et al, 1992) and that this human nature exists at the level of adapted psychological mechanisms (i.e. mental modules). Claims such as the above immediately give cause for those with worries about the aptness of essentialist theories to perk up their ears. However, before one too hastily rejects the views of Tooby, Cosmides and Barkow1, one must be careful to give the three their due, and be sure of exactly what they are claiming.

The opinions of the three expressed in *The Adapted Mind* can be taken to imply either one of two things. One interpretation of the three's arguments, such as "(there is) a single, universal pan human design" (Barkow et al 1992) is to believe that Tooby, Cosmides and Barkow are attempting to suggest a type identity between the mental modules from one person to another. Another, weaker interpretation is that the three hold the view that everyone has similar mental modules that fall under some sort of normal range. It is not completely clear which of these views the three hold, but in either case there are reasons to doubt that the nature of mental modules could be as they describe. Since it is not evident *prima facie* which of these views the three hold, it would be prudent to explore and consider objections for both.

First let us explore the mental modules as type identical across the species *Homo sapiens*. It seems from the three's assertions in *The Adapted Mind*, that they believe that though behavior

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1 From this point on for reasons of me being too lazy to repeatedly type out their entire names, Tooby, Cosmides and Barkow will be referred to as "the three"

may vary from one individual to another, the mechanisms behind these behaviors are structurally and functionally identical. They believe that variation of action and response is not a phenomenon due to different cognitive and mental mechanisms within the brains of different individuals, but a result of differing environmental inputs. Such a view is evident in claims of theirs such as:

> (The human mind is not) an externally programmed general-purpose computer lacking in a richly defined evolved structure. Instead, human culture and social behavior is richly variable because it is generated by an incredibly intricate contingent set of functional programs that use and process information that is provided both intentionally and unintentionally by other human beings (Barkow et al 1992).

This view of Tooby, Cosmides, and Barkow can be interpreted to be making claims similar to those of the traditional essentialist. Indeed, the picture that the three provide of mental modules sounds very much akin to what Aristotle might claim about the essences of a natural kind, with the exception that the three hold that mental mechanisms are contingent rather than necessary (Sober, 1992).2 Their talk about the "richly defined evolved structure" (Barkow et al 1992) being triggered or suppressed by "information that is provided both intentionally and unintentionally by other human beings" (Barkow et al 1992), is nearly identical to Aristotle's discussions of the natural states of things versus the interfering forces which influence the manifestation of those states.

It seems that there is reasonable justification to believe that Tooby, Cosmides and Barkow have traditional essentialist leanings, and that they believe that the mental modules of all humans share a common structure and function. However one should not ignore the other possible interpretation of the three's claims about mental modules. Perhaps they are not making the strong claim that mental modules are completely invariable from one person to the next, perhaps they are just claiming that there is a normal set of mental modules that the vast majority of the population possess. Though there is no explicit mention of this alternate view within the literature, it is reasonable to believe that the three may hold this view given the abounding objections against the belief that there exist universal traits that are strictly identical across members of a species.

Now that we have examined what the opinions of Barkow, Cosmides and Tooby are, it seems natural to move to the reasons that they believe that the nature mental modules is as they

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2 See Aristotle's *Metaphysics* for a more thorough exploration of this issue.

claim. The three believe that mental modules developed as they have due to the fact that they evolved in prehistoric *Homo sapiens* to deal with the stresses that faced a hunter-gatherer species. In the two million or so years that humans spent as hunter-gatherers, in the three's opinion, our minds adapted trait by trait, mutation by mutation, to meet the pressures that were imposed upon us by the environment until we arrived at the point where we are now at. Based upon this view and the three's interpretation of Mendelian genetics, the three develop a theory of the development of the mental mechanisms that we have, and of why these mechanisms are of a universal pan-human design.

Barkow, Cosmides and Tooby believe that given the complexity of the system of our mental modules, the length of the gene sequences necessary to encode such a system, and the fact that our reproduction involves the joining of two different sets of gametes which must be compatible, we cannot significantly differ in terms of our mental modules. The three believe if by happenstance an individual was born with a set of mental modules that deviated significantly from the normal population, that individual's genotype would differ so much that they would be unable to parent viable offspring. The individual's gametes would be so incompatible that they would not be able to combine with potential mates. The probability of them meeting and mating with another who had the same mutation would be so low that the new module would not continue to survive.3 They make arguments for this case with references to what they believe is the adaptational process that led to the current state of the vertebrate eye.

Barkow, Tooby and Cosmides claim that the eyes of vertebrates are a very complex system, with many adaptations to deal with a plethora of pressures that our environment challenges us with. The three believe that such being the case, the eye is much like the mental modules that they posit. Mental modules, like eyes, adapted over many millennia, one beneficial mutation at a time to arrive at the complex structure that exists today. They also point out that given the common adaptational history the mechanisms found in vertebrates are nearly identical. Among the commonalities across vertebrate species the three list such structural traits as the construction of the retina, the photo-reactive pigments, and so on; they also list the functional commonalities such as the iris' ability to adapt the aperture of the pupil in response to changes in ambient illumination and the stereoscopic coordination of the eyes that is necessary for three dimensional vision (Barkow et al, 1992). They also believe that, given the similarity of traits

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3 This view is more clearly expressed on page 78 of *The Adapted Mind*

across species, within species, such as *Homo sapiens*, besides some very minor differences, such as the colour of one's irises, eyes are essentially identical in structure and function. With this conclusion in mind, the three generalize to mental modules, and claim that it is plausible, given the complexity of mental modules, which equals if not exceeds the complexity of eyes, that there is little likelihood that there is any variation in the mechanisms of human mentality.

It seems, after some consideration, that the evidence that Tooby, Cosmides and Barkow point to as rational to draw the conclusion that mental modules are universal, is oversimplified if not leading to completely fallacious inferences. One might be concerned if the three are really saying what they seem to be saying, given their knowledge of issues within the field of biology and genetics. It would seem more reasonable for the three not to make as strong and difficult to defend claim as: eyes, and therefore mental modules, due to their evolutionary histories, must be structurally and functionally identical and make a weaker more defensible claim, such as there is a normal set of traits which nearly all of the population possess. However it the arguments for universality are clearly stated as arguments for universality in the section titled: "What Adaptations Look Like" in *The Adapted Mind* (Barkow et al, 1992). It should be noted though, that even if the three were making the weaker claim, there would still be reason that such a claim should be doubted, which will be discussed later on in this paper.

Now that we have gone over the claims that Barkow, Cosmides, and Tooby, and the rationale behind their views, it seems to be a natural time to discuss some reasons why their views should be called into question. First let us examine their example of the vertebrate eye. They believe that a complex system such as the eye demonstrates to us why we should believe that mental modules should be of "universal pan human design" (Barkow et al, 1992). However if such an example does anything, it informs us of why we should believe that there is a substantial amount of variance within any population for any adequately complex set of traits.

The three believe that optical organelle are nearly identical across the human species, but this simply is not so. An example of this would be color blindness. One in five males and a somewhat lower number of females are afflicted with some level of inability to discriminate at least some of the colours that the "average" person can. Protanopia, deuternopia and tritanopia are fairly common within the population, they are conditions affecting the structures involved in vision, and moreover they are the result of genetic defects (Carlson, 1998). Not only is color blindness caused by genetic variation, it is a genetic variation which leads to the manifestation of a maladaptive trait, or set of traits. Yet these traits are not extinguished as one would assume, given the three's claims about genetics, they survive and pass on from one generation to the next.

In addition to the worries about the analogy between the vertebrate eye and mental modules that Tooby, Cosmides and Barkow makes, there are theoretical reasons within the philosophy of biology to doubt views that posit universal invariant traits. Some of these arguments can be found in the third chapter of *The Poverty of the Linnaean Hierarchy* by Marc Ereshefsky (2001). In this chapter Ereshefsky makes a claim that has very important implications for those who take the three's view to indicate that mental modules are universal and invariant. Ereshefsky, in his discussion about essentialism, notices that speciation is a slow gradual process. There are no clean cut lines when one species becomes another, rather evolution and speciation is a vague blurry process. Speciation is much like a balding man, there is no specific instant when the man goes from having a head of hair to being bald. The process, like the process of species delineation is gradual and has no clear boundaries. This being the case, at any given time there should be members within any population that carries some genetic material that differs from the rest of the population, whether this material is able to "spread" and become common within the population is a matter of how the phenetic expression of the gene affects its carriers ability to survive, but the case still stands such genetic variations are found in any population of sufficient size.

Even Barkow, Tooby, and Cosmides make similar claims as those of Ereshefsky in their discussion of the vertebrate eye. They claim that our eyes evolved slowly and gradually trait by trait to deal with the adaptive pressures which faced our ancestors. It seems reasonable to assume then that they would also believe that our ancestors had variation within their populations, otherwise where would the traits come from to be selected for? So why is it that they hold that there is no significant variation within our population? Is it that they believe that they believe that somehow the process of evolution has stopped, and we are no longer evolving? This might seem like an unreasonable claim, and it is, but it would have to be the claim that is being made if one were indeed to believe that there could be no substantial amount of variation within a complex set of traits.

The next view that we will examine as a counter to those of Barkow, Cosmides and Tooby is that of Elliott Sober, as are found in his paper "Evolution, Population, and Essentialism" (Sober, 1992). Sober's comments on the problems of theoretical assumptions about there being a set of traits being normal for a populations are perhaps the most difficult for the three evolutionary psychologists to deal with. In “Evolution, Population, and Essentialism” Sober discusses why he believes “typologist” thinking is mistaken when applied to fields such as biology. Instead he supports a view of “population thinking.” While Sober’s view are not strictly ant-essentialist in a global sense, he makes the claim that it would be an error to assume that there is a normal or natural type for any trait, and that variation in the expression of the trait is due to interfering outside forces. He believes instead that for any aspect of a population there is a bell curve of variation, and that there is no single place in the curve which should be assigned primacy and considered the norm (Sober, 1992). There may be some spot on the curve under which the majority of the population falls, but even if some individual happens to fall outside one standard deviation from the mean, or some other arbitrarily chosen cut-off, that individual should not be considered somehow unnatural or abnormal.

In terms of genetics Sober points out while “according to natural state model(s) (such as Barkow, Tooby and Cosmides’) there is a single genotype or restricted class of genotypes, which count as the natural states of the population or species,” (Sober, 1992) in actuality “statistical profiles of genotypic variance within a population enshrine no such difference. Genotypes differ from each other in frequency; but unusual genotypes are not in any literal sense to be understood as deviations from type” (Sober, 1992). In addition to this he makes it clear, that this is a useful and necessary property for a species to have.

Without an adequate amount of variation of genetic material within a population, that population would soon become extinct due to a lack of adaptability, for there is no trait that is “fittest for all environments” nor is there a certain “genotype being the natural state of a species in terms of maximal fitness” (Sober, 1992). Such being the case it would be reasonable to make the assertion that it is quite possible that individuals within the species *Homo sapiens* could carry different genetic material for the expression of different mental modules. Moreover, it seems quite likely that there is at least some portion of the population who does in actuality bear these genes, and due to the expression of these genes, live out their lives with different mental modules than those of others.

Sober makes another argument which is quite troubling for the views of Tooby, Cosmides and Barkow. He points out that even in individuals sharing common genotypes, they may very well express them in very different ways due to differing environmental conditions; so that even with a common genotype individuals can have very different phenotypic features. He uses an example referring to the differing height of genetically identical cornstalks grown in different soil conditions, but to be more on topic, I will use the example of fetal alcohol syndrome (FAS).

Fetal alcohol syndrome is characterized by several “abnormalities” such as mental retardation, retarded growth, attention problems, learning difficulties, small head circumference, shortened eyelids, a flattened jaw line, and a poorly developed philtrum and thin upper lip (Nietzel et al, 1998). These “abnormalities” are not the result of genetic variation, but rather are the result of *in utero* conditions. Those born with FAS do not have the condition because they differ genetically from those without FAS, but because their mothers consumed large4 amounts of alcohol during pregnancy. Again, as he did with genotypes, Sober strengthens his claim by pointing out that one should not consider any specific set of environmental conditions to be normal or the fittest for a species, nor should one have the belief that for any genotype there is a single phenotype that is the normal expression of it (Sober, 1992). He claims that any interaction between genotype and environment that occurs to cause the expression of some trait is as “natural” as any other since all these interactions happen in nature (Sober, 1992). Also since all these interactions happen in nature, the claim that certain interactions were unnatural or abnormal would simply reflect our biases and have no place in a proper empirical undertaking.

With consideration of the views of Marc Ereshefsky and Elliott Sober, one cannot help but to question the aptness and veracity of the claims of Tooby, Cosmides and Barkow. If the process of evolution is to continue, there must be constant mutations and variations in any given genome to provide the traits for selection. If human mental structures and functions were as rigidly defined and static as evolutionary psychologists claim, then the species *Homo sapiens* would be in dire straits indeed. For, as Sober pointed out, there is no single set of traits which is the fittest for all environments, there are always a changing dynamic set of pressures driving any organism to adapt. If one were to consider evolution as the driving force shaping the human mind, one must keep the fluid nature of populations in mind. Evolutionary psychology is a start towards an understanding of how our species history has shaped the humans now living in the world, but it is not the end all and be all. Barkow, Tooby and Cosmides views are on the right

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4 Studies have shown that as few as two drinks per day during the midcourse of pregnancy can lead to an average drop of 7 IQ points in the child (Nietzel et al, 1998).

track, but without more consideration to what we have learned about genetic variation within populations, it fails to get the job done.

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AUTONOMOUS NAVIGATION USING VISUAL LANDMARKS

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ABSTRACT

A method whereby an autonomous robot can navigate in a known, unmodified environment is presented. The method uses visual landmarks, matching previously stored "snapshots" of the environment to recognise its location. This landmark detection method, augmented with other systems such as ultrasonics and a memory of previous location, permits reliable location in an environment. By performing simple actions such as turning and following walls, navigation is made possible. The Tao 7 experimental wheelchair project, using the concepts developed in this paper, is described. The wheelchair demonstrates that these simple behaviours can generate a creature capable of navigating in an unmodified environment. Problems encountered and possible resolutions are considered.

Revision: 2.4

1 INTRODUCTION

This paper examines a means whereby a mobile robot can automatically and unambiguously determine its position in a known environment, using a system composed of behaviours that give ambiguous results. This landmark detection permits the robot to navigate using actions that link together points on a map.

This work is based loosely on that described by Edwards [1]. It extends previous navigation work by relying to a large extent on uncertain visual landmark detection.

1.1 BACKGROUND

The Behaviour Based approach to machine intelligence is the basis for the work described in this document. Behaviour Based robotics was developed by Rodney Brooks [2]; in this design philosophy, the Subsumption Architecture permits a handful of very simple behaviours to guide the robot. These behaviours link sensory inputs to outputs, using no more processing than simple finite-state machines, augmented with timing elements [3].

Much work has been done developing simple behaviours permitting the robot to avoid collisions with static or moving obstacles and to wander aimlessly around the unmodified environment. The focus of this paper is an additional behaviour: a navigation behaviour, by which the robot can arrive at a given location in the environment. The navigation behaviour relies on previously existing collision avoidance behaviours, but does not modify them except by selectively overriding them.

1.2 ANIMAL NAVIGATION

A number of methods are used by animals to navigate in their environment. It is worth considering them as inspiration, because evolved solutions can often be both effective and simple.

Digger wasps use landmarks to return to the nest after foraging [4, pg 435]. Although the wasp purposely obscures and camou?ages the entrance, it can re-find it by memorizing the location in space of the entrance with respect to nearby landmarks.

Orientation for the purpose of migration is performed by birds using a large number of approaches: star patterns, the magnetic field of the earth, the position of the sun with respect to time of day, and other approaches [4, pg 422].

2 LANDMARK DETECTION

The navigation method will require a method to detect the current landmark. How is this to be achieved?

2.1 VISUAL LANDMARK DETECTION

A very simple approach to landmark detection is described by Edwards [1], using first a neural network approach, then an algorithm known as the pattern vector method. Poor recognition was demonstrated by the neural network, so only the pattern vector method will be considered. The detecting is performed in the same way on separate grey and colour data; for clarity, only the grey segment will be discussed.

When a landmark is captured, a very low resolution (eg 8 × 8) image is taken of a region in the middle of the field of view. The grey and colour values of this image are stored in memory. Now when the robot is searching for a match, it compares each "snapshot" with the image currently in view. Figure 1 shows a typical landmark.

Figure 1: A typical landmark

The comparison involves simply taking the absolute difference in intensity for each pixel in the snapshot. These values are given weights proportional to height in the image, as pixels which are higher (and hence closer to the horizon) tend to change less as discussed by Gibson [5].

Once the pixels have been multiplied by their coefficients, they are summed then stored as the error associated with detecting that landmark. A smaller error indicates a closer match. Where a, s, p, and e are the coefficients, stored snapshot, currently-visible picture, and error, respectively:

$$e = \sum_{j=1}^{m} \alpha_j \sum_{i=1}^{n} |s_{i,j} - p_{i,j}|$$

Where n and m are the width and height of the snapshot, in pixels.

The smallest error for each landmark is measured by comparing the landmark with numerous points in the visible image, "sliding" the comparison across to get a close match. This enlarges the region of space at which the robot can detect each landmark.

The error is calculated for any number of landmarks. Under the Subsumption Architecture each landmark conceptually becomes its own Augmented Finite State Machine (AFSM), so detection is performed in parallel, and hence in constant time.5

3 AUTONOMOUS NAVIGATION

With the landmark detection method described in Section 2. the question arises of how to navigate using this information. One achievable method is to join the landmarks together in a topological map, and to program different actions at each landmark which cause the robot to arrive at a specific nearby landmark. By then joining together a sequence of small goals, the ultimate destination can be reached.

3.1 THE MAP

The map is stored in a data structure isomorphic to a directed graph [6]. Each node corresponds to a landmark; by knowing which landmark the robot came from and which is has arrived at, it can be unambiguously etermined which directed edge of the graph the robot has crossed. In other words, orientation of the robot ollows naturally from the current and previous positions.

Each node contains information about incoming connections, and how to get from each incoming connection o the outgoing connections using an action.

Presently, a hand-generated map is used. Ultimately the robot must also be able to generate and extend he map by exploration.

3.2 ACTIONS

When a landmark is detected, the robot evaluates the map by checking each connection from the current landmark, then checking each connection from that landmark, and so on, determining the topologically shortest route (through the smallest number of landmarks) to the goal. It can then determine the next landmark to head towards. Once the short term goal has been determined, it simply initiates the action at that landmark which links the previous landmark with

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5 Actual implementations rarely use separate hardware for each behaviour.

the next landmark. These actions are simple motions, such as “turn left” or “follow a wall on the right.” The robot performs these actions for a specified time, then continues wandering. The environment guides it to the next landmark; it will try to move straight, but if constrained between two walls, for example, it will keep itself between them, even if they curve.

4 IMPROVED LANDMARK DETECTION

The pattern vector method described in Section 2, although computationally very simple, doesn’t work very well. An error of zero almost never occurs, and many false positives are encountered. By itself, the pattern vector method of landmark detection is inadequate.

The first thought to remedy the situation is to improve the complexity of the vision processing algorithm, and to make each landmark contain more information about the image. A higher resolution image could be used, or an attempt could be made to match under graphical operations such as rotate, scale, and skew. However, even a human provided with a high resolution image of two similar landmarks is unable to tell the difference. Figure 2 shows two similar landmarks encountered in a typical office environment. (These were not selected because they are unusually difficult to tell apart; they are real, different landmarks which must be distinguished to navigate successfully in the office.)

Clearly, visual discrimination of such images cannot by done by the robot; it cannot even be done by a human. Although improvements in visual discrimination are quite possible and worth considering, other approaches to landmark detection must be considered.

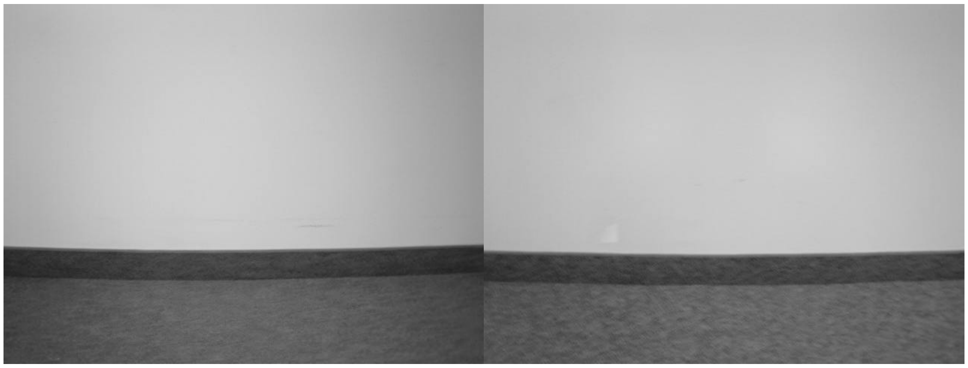

Figure 2: Two similar photos; how can the robot distinguish these locations?

Brooks [7] presents the idea of making easily distinguishable landmarks, such as bar coded signs. This idea is unacceptable to many researchers, including himself, because the robot must be capable of working in a unmodified environment. Some animals are successful at navigating without changing their environment, as discussed in Section 1.2, so this is not an impossible task.

So the problem is that the robot cannot recognise a landmark simply by looking at a photo of it. Therefore, in addition to comparing the image to old photos, we need some other detection circuitry. This can be done in number of distinct ways:

1. Evaluation of connectivity of the map
2. Additional (non-visual) perception
3. Timing between landmarks

Each deserves some attention.

4.1 MAP CONNECTIVITY ANALYSIS

Given any landmark in the map, only adjacent landmarks can be reached, provided no landmarks are missed. For this reason there is no need to consider matches of any landmarks except for those which are adjacent to the current landmark. This decreases the possibility of a false positive, as only positive results from adjacent landmarks are considered. Four connections is sufficient for most office environments, as shown by Mataric [8]. When the robot is seeking a goal, only positive detection results for the target landmark are considered. Confusion is then only possible if a scene that the robot cannot distinguish from the target is encountered while travelling towards the target.

4.2 NON-VISUAL PERCEPTION

There is no reason that a landmark must solely be a visual cue. Scent is used by dogs and other mammals, honey-bees and others [4, pg 486-490]; numerous air-breathing water creatures, such as amphibians and insects, use gravity for orientation [4, pg 433]. A number of other approaches for detecting landmarks are worth considering.

As shown by Mataric [8], compass readings can be of assistance in detecting landmarks. Even landmarks which are visually very similar but at different angles with respect to north can be distinguished. The images in Figure 2, for example, are at the ends of perpendicular hallways.

Using the Global Position System [9] is not a good solution, as the system is generally unusable indoors.

It would be acceptable for certain applications, including navigation of automobiles, aircraft, and military devices such as autonomous cruise missiles.

Many Subsumption Architecture robots have multiple sensors and types of sensors. It has been shown [8] that navigation can be done entirely using ultrasonic sensors and compass orientation. This was demonstrated by building up confidences in the state of the surroundings: the presence of a wall on either side, a curve, or other features large enough to be detected using ultrasonic sensors.

By considering the state of additional sensors when detecting landmarks, many false detections can be discounted. A behaviour can prevent landmarks from becoming active if the state is incorrect. If, for example, the landmark should have a wall on the left but one cannot be detected, that landmark would not become active.

4.3 TIMING

Measuring the time elapsed between landmarks can also be used for verifying correct position. If the trip between landmarks typically takes place in a particular length of time, then if the second landmark is detected a very short time after the first, it can be considered a false match; likewise, if the second landmark has not been detected after a very long time, the robot can consider itself lost, and attempt to reorient itself in the map. Introspective experience suggests that humans do this sort of thing. If following a poorly known trail, one will eventually feel “I should have passed that ugly office tower by now,” and re-evaluate one’s position.

Likewise, if a landmark similar to the expected landmark is detected well before it is expected, it can be ignored.

4.4 VISUAL IMPROVEMENTS

Once these other methods have been considered, it is worth considering possible improvements in the vision based landmark recognition. Landmark recognition by the pattern-vector method has problems with lighting levels. If the blinds are opened or the lights switched off, successful recognition drops. This is because a small error is introduced into every pixel of the image. When these small errors are summed, the result is quite large. This problem could be solved by examining the distribution of the error. It is almost perfectly ?at; It should be possible to recognise this sort of pattern in the difference.

Distinct landmarks under similar lighting will be very different; instead of having the difference spread evenly across the image, the pixels will have large differences in some areas, and smaller differences in others.

5 A PHYSICAL ROBOT

Landmark detection and navigation using the concepts described above was implemented on the Tao 7 autonomous wheelchair.

5.1 HARDWARE

The Tao 7 is based on a Jazzy 1120 2000 purchased from Pride Mobility Products. A box inside contains a handful of computer boards. The main CPU board contains a Motorola 68332 processor running at 32 MHz. One megabyte of memory is available on this board. A Texas Instruments 6202 Digital Signal Processor running at 200 MHz performs vision calculation, and communicates with the main board over an RS-232 serial link. Figure 3 shows the Tao 7.

Eleven active infrared sensors and eight ultrasonic sensors are mounted around the robot, of which the majority are at the front.

The Tao 7 has several behaviours, listed in decreasing priority: infrared sensors, ultrasonic sensors, vision-based collision avoidance, and landmark detection/map following.

The avoidance and navigation behaviour source code occupies 7244 lines; the vision landmark detection code is 4621 lines. Clearly landmark detection and navigation can be performed without highly involved algorithms or powerful computers.

5.2 ENVIRONMENT

Extensive testing was performed in an unmodified office environment. The walls were blank white, and the floors were dark carpet; coloured desks, plants, people, and other obstruction were present. See Figure 4.

Figure 3: The Tao 7 Autonomous Wheelchair

A map was created with 24 landmarks covering a figure-eight shaped region in the office. Figure 5 shows the layout of the office. The landmarks were chosen to be at turns and important point in the corridors.

5.3 MAP

Each landmark had at least two outgoing connections, one for continuing and one for returning; the only exceptions are a small number of landmarks added to ensure that a nearby landmark is approached from a consistent angle. The landmarks clustered around the reception/co-ops crossover point had extra connections to handle the crossing.

5.4 LANDMARK DETECTION

The three approaches described above for increasing landmark detection accuracy were implemented on the Tao 7.

5.4.1 MAP CONNECTIVITY

Trial and error modification of the map was used to generate a usable map. Under certain circumstances it was difficult to have the robot approach landmarks in a sufficiently consistent manner. By arriving at an unusual angle the robot could either not recognise where it was, or could recognise the landmark, but the action required for one location would not function for another area within the same landmark. This problem could be handled partially by adding intermediate landmarks. Near reception, for example, landmarks were added for this purpose. By guiding the robot to the left wall it could arrive reliably at the next landmark.

5.4.2 NON-VISUAL PERCEPTION

Using the sensors already present on the Tao 7, a weak ultrasonic landmark recognition system was added alongside the visual landmark recognition; a behaviour was added which marks as invalid landmark guesses which do not make sense considering the state of the walls on either side of the robot. Each landmark includes information as to where walls should be to detect it: on the left, right, both or neither. If there exists a landmark with a larger (and still sufficiently small) visual error but with wall states matching the current condition, it will not be marked as invalid by the wall-checking behaviour, and will be successfully detected.

Figure 4: A corridor in the office

This technique improved landmark detection accuracy enormously. It is not without its problems — if the corridor is wide, the position of the wheelchair can vary considerably from run to run. A landmark that had a wall on the left on one test may be approached farther to the right in the corridor, and have a wall instead on the right, or no detectable walls at all. For these situations code was added so that a landmark may instead indicate that, for its walls, “the answer is unclear.” The wall-checking behaviour is then suppressed when detecting that landmark.

5.4.3 TIMING

Timing between landmarks was a considerable problem, especially when driving clockwise around the northern loop or counter-clockwise around the southern loop; this is where the images of Figure 2 originate. After detecting the first landmark it would accept detection of the second, which, due to its visual similarity, would be immediately activated. By suppressing detection of the next landmark until the timing of the action of the previous landmark had expired, and by ensuring this action moved the robot out of the region of visual similarity, the timing issue was resolved.

5.5 LIMITATIONS

5.5.1 OPEN SPACE

Numerous problems were encountered dealing with the open space near reception. This is why a great deal of effort was required to program the robot to reliably navigate in this open area; if the robot closely follows the wall it can get guidance from this wall. In general, the navigation methods described above do not function well when there is little guidance from the environment.

Guidance from the environment can take many forms. In the office, the robot was restricted by walls, cubicle dividers, desks, chairs, potted plants, and other objects. A robot designed to navigate in a different environment would need to take path guidance cues from other sources.

Driving outside in a city, for example, the chair would need to be able to extract guidance from sidewalks, by detecting the edges. An autonomous automobile would extract path cues from the edges of the road or lane and the presence of other vehicles. Some driving “aids” have been described in IEEE Spectrum [10].

The concept of intelligence being based on interaction in the world is expressed by Brooks [2], but even more clearly by Chris Malcolm [11].

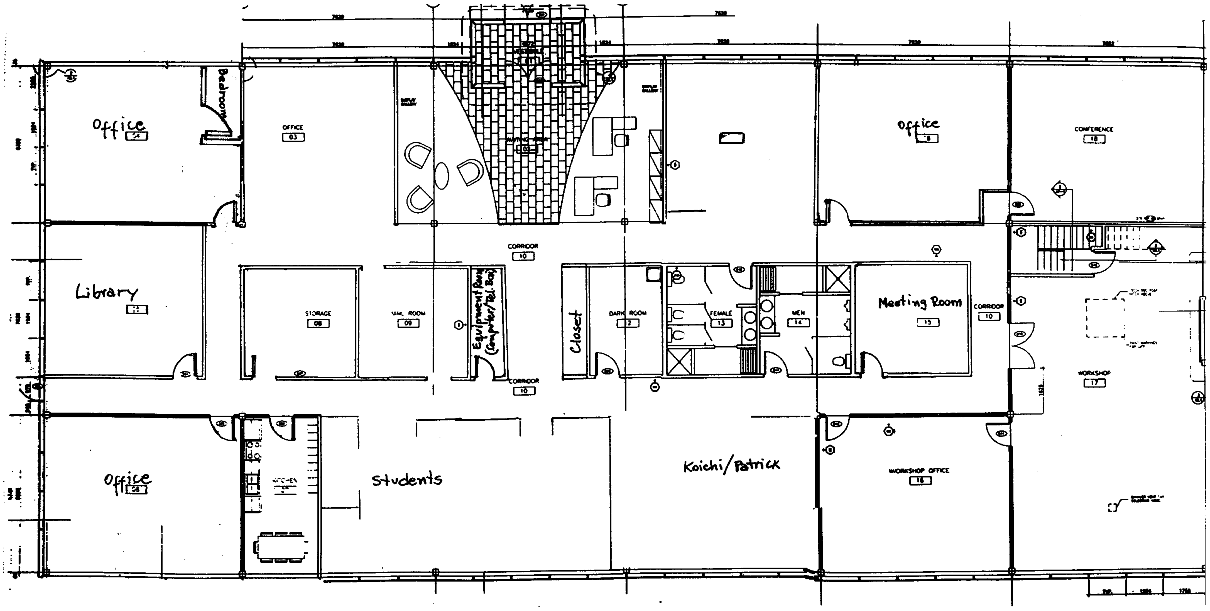

Figure 5: Layout of Tao 7’s environment

It is interesting to note that humans also cannot navigate successfully without guidance from some overriding system. Directional and positional techniques and instruments (star navigation, the magnetic compass, sextant, and GPS) were required to allow navigation in an environment that is otherwise guidance free.

5.5.2 DETECTION FAILURE

The landmark detection behaviours still occasionally miss landmarks. Although this is very rare in the office environment, it ultimately cannot be avoided. Sometimes a landmark is obscured and the robot drives past it, it will eventually get to another landmark, but will not expect it, and so will not recognise it. It will also continue to expect the landmark it missed, regardless how much time elapses without finding it.

Due to the nature of Behaviour Based systems, these additions provide little benefit when considered individually, but when combined produce large improvements.

6 CONCLUSIONS

A typical office environment can successfully be navigated by an autonomous robot. Because landmarks only affect nearby landmarks, the map can be expanded without any limit besides available memory.

Where the environment provides very little guidance, in large empty rooms, fields, or lakes and oceans, landmark based navigation cannot easily be implemented. This matches biological models, which use other techniques such as directional guidance for non-organised environments.

7 RECOMMENDATIONS

Navigation is a broad topic, and there is much to be done before robots will be able to navigate in arbitrary environments. Some of the next steps are apparent; some suggestions are presented.

7.1 DESIGN IMPROVEMENTS

The robot, after finding a landmark, expects the next landmark. Currently, this expectation never ends, even if a very long time passes. Code should be added to permit the robot to determine when it is lost, and respond appropriately.

When creating the map, a large amount of "guess and check" was required. This means that switching to a different building is a difficult task; the map must be re-developed, a task nearly as difficult as making the first map. Manual map generation should be simplified drastically.

7.2 FURTHER STUDY

Detection failures can be reduced by expecting a larger number of landmarks: not only the next landmark, but other nearby landmarks. This may be a difficult task. In general the robot should have a level of confidence in its location, which is modified by seeing landmarks and timing. From certainty in its position the confidence would gradually decrease until it finds another landmark.

Free space navigation, although partially handled by adding landmarks, is quite a different task from environmentally-guided navigation. It requires as a map either a much more thickly connected graph or some other representation of space. Considering that the majority of human environments are well delineated (eg corridors by walls, roads by painted lines) this does not significantly limit applications of the ideas developed above.

It will not be acceptable to require a human to manually generate a map for every environment. The robot must be developed so that it can autonomously generate a map by wandering around. Giving it the name of each location, eg “this is the kitchen,” “this is my office,” is the most that the human should be forced to do.

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PROBING THE LIMITS OF MIND AND BRAIN

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The Brain is wider than the Sky
For put them side by side
The one the other will contain
With ease and You beside
- Emily Dickinson (1896)

1. INTRODUCTION

This essay has two objectives: first, to show the relevance of cognitive neuroscience to philosophy, and second, to propose an area of research that can be addressed using philosophical and neuroscientific methods.

Regarding the first objective, Stone & Davies (1993) have previously argued that the results of cognitive neuropsychology have implications for theory in the philosophy of mind. Their appeal to relevance is limited to the functional organization of mind, as revealed by cognitive neuropsychological data. As Stone & Davies see it, “cognitive neuropsychology reckons the *neurophysiological* details of patients to be more or less irrelevant” (emphasis mine). While I believe that this may be true of investigations in cognitive *neuropsychology*, I believe that cognitive *neuroscience*, which takes such neurophysiological details into account, can also be shown to be relevant to philosophical discussion.

With respect to the second objective, I hope to show that aspects of metaphysics can inform, and be informed, by data from cognitive neuroscience. P. F. Strawson (1959) describes the field of *descriptive metaphysics* as “content to describe the actual structure of our thought about the world.” It is becoming increasingly apparent through work in the fields of cognitive neuropsychology and cognitive neuroscience that thought is constrained in some way by brain function. I do not wish to argue here that mental states are identical to, or even reducable to, brain states, but it does seem to be an inescapable fact that there is some kind of a correlation between the two. That a correlation exists, will suffice for the moment as an assumption from which to work. It may prove to be an incorrect assumption, but demonstrating the independence of thought from brain function remains an open challenge.

In a later section, I will show how Strawson's account of persons (1959) parallels empirical findings in cognitive neuroscience regarding 'theory of mind'. I suggest that this kind of parallelism between philosophy and neuroscience reveals a pattern of convergent results regarding the limitations of mind. Philosophy can provide a map of "the bounds of reason" in terms of conceptual structure, and cognitive neuroscience can show us how these boundaries come to be as they are.

2. THE RELEVANCE OF COGNITIVE NEUROSCIENCE TO PHILOSOPHY

In giving an argument for the relevance of cognitive neuro*psychology* to philosophers, Stone & Davies (1993) stop short of admitting the relevance of "neurophysiological details". This section outlines their argument, and extends it to include such details, bringing cognitive neuroscience into the picture

2.1. FIRST, COGNITIVE NEUROPSYCHOLOGY AND THE PHILOSOPHY OF MIND

Stone & Davies (1993) believe that cognitive neuropsychology can be of interest to philosophers in two ways. First, "philosophers can take a metatheoretical interest in the assumptions and arguments of cognitive neuropsychology." In taking up this role, philosophers give clarity and direction to cognitive neuropsychology by building theoretical foundations for methods, and helping to shape cognitive neuropsychological concepts through criticism. Metatheoretical philosophers are outside observers, commenting on the methods and concepts of an empirical field.

Second, cognitive neuropsychology can play an auxiliary role to philosophy. The investigation of certain philosophical problems (particularly in philosophy of mind) can be guided by neuropsychological data. Philosophers can, in some cases, take empirical data and use it to shed light on their own problem of interest. This second intersection of the fields of philosophy and neuropsychology will be one of the concerns of this essay.

But how can an empirical discipline like cognitive neuropsychology inform a discipline that often deals in *a priori* truth, as philosophy does? It could be argued that philosophy deals in a different kind of explanation than cognitive neuropsychology. On this understanding of philosophy, empirical data would be, for the most part, irrelevant. However, Stone & Davies (1993) show that a cognitive neuropsychological explanation of prosopagnosia (a specific disability of face recognition) could provide an *alternative* to certain philosophical explanations. If their comparison of the explanations is legitimate –- if, in their fully extended interpretation, the explanations do conflict -- then we know that at least in some cases, that there is competition between neuropsychological and philosophical theory. Competition would imply that both accounts do, in fact, operate on the same level, and address the same (or at least similar) questions. For Stone & Davies' argument, the truth or falsity of either explanation is irrelevant: "[t]he possibility that the explanations are in competition is all we need to make our point."

This kind of competition can be put to good use in the realm of philosophy, particularly when cognitive neuropsychology, to use Stone & Davies' phrase, "[makes] good on failures of imagination." Empirical data can present counterexamples to what are taken to be *a priori* facts, and may reveal philosophical errors. This is not to say that all disagreements entail changes in philosophy; instead such disagreements can lead to renewed discussion.

Stone & Davies sum up the interaction of philosophy and cognitive neuropsychology beautifully when they say:

> Often philosophical theory uncovers necessary conditions for the application of personal level folk psychological properties. Subpersonal level cognitive psychology tells whether, and if so how, those necessary conditions are met.

2.2. ENTER COGNITIVE NEUROSCIENCE

The interactive relationship of cognitive neuropsychology with philosophy is what opens the door for cognitive neuroscience to enter into philosophical debate. Stone & Davies (1993) admit that "the claim that neurophysiological details are not especially relevant is usually pragmatically grounded." Stone & Davies quote cognitive scientist Tim Shallice, who wrote in 1988, "[t]o hope for an advance in theories of the functional organisation of cognition by paying special attention to issues of localisation is not, *at present*, a promising strategy" (emphasis mine). While Shallice's statement may have been true when it was written, the 'unpromising strategy' of localisation has since been pursued, and it now one of the core methods of cognitive neuroscience. I would argue that relating neurophysiology to the functional structure of cognition has become somewhat easier since the writing of Stone & Davies' paper. Stone & Davies write that, “virtually all cognitive neuropsychologists agree that . . . psychological theories are constrained from below by the facts of neurophysiology.” It is the details of these constraints that cognitive neuroscience is able to contribute.

Cognitive neuroscience augments the single case study methodology characteristic of cognitive neuropsychology with neuroimaging studies and computational modelling. With these additions, cognitive neuroscience is able to give a fuller picture of the neurological structure that underlies the functional architecture of cognition. It is an assumption of cognitive neuroscience that the functional components of cognition are realized by neural mechanisms. This can be (but is not always) differentiated from the related assumption that mind is reducable to brain function. It is not essential to cognitive neuroscience that the entirety of mental life be reducable to brain function; it is only essential that some systematic relationship exist between the mental world and the neurophysiological world for some set of mental processes. If mental processes turned out to be something entirely different from brain function, but were still inextricably bound up with brain activity, cognitive neuroscience could still proceed. At present, most of the research in cognitive neuroscience is focussed on unconscious (subpersonal) processes, which distances the field from some of the problems that plague reductionists, particularly those concerning subjective experience (e.g., qualia). The lingering issue of whether unconscious processes are correctly called ‘mental’ processes is discussed in Stone & Davies’ paper. *Contra* Wittgenstein, their conclusion is that so long as what is explained by unconscious processes comes into contact with the accounts given by philosophy, what is ‘mental,’ is merely a terminological question, and not a methodological one.

Cognitive neuroscience assumes that the operational characteristics of functional modules posited by cognitive neuropsychologists can be determined, in part, by their physical realization. In other words, how a particular mental process works can be revealed by the way that the mental process is instantiated in the brain. This is not to say that a mental process could not be instantiated differently; only that its *actual* instantiation yields clues about its function. Functional modules can be viewed in terms of the computational paradigm: functions are programs that use neural mechanisms as hardware. The kinds of functional module that one could expect to find are limited by the available neural ‘hardware’. Furthermore, certain identified functional modules are localisable to particular brain areas. These areas, in turn, appear to have an organization that is tailored specifically to the operation of that particular function. By observing neurophysiological structure and activity in restricted areas of the brain, it may be possible to (a) discover new functional modules, and (b) refine our understanding of the internal workings of the functional modules already discovered.

What do these kinds of discoveries mean to philosophy? Stone & Davies (1993) say that,

> Cognitive neuropsychology provides us with a much more fine-grained account of the mental than that given us by those pre-theoretical intuitions upon which many of our philosophical claims are (inevitably) based.

Cognitive neuroscience extends the level of specificity further, allowing functional modules to be described in terms of neurological, and perhaps even computational, form. A taxonomy of functional modules would enable more precise theories of mental process to be compared to philosophical theories, hopefully enhancing the precision of the philosophy. As Stone & Davies say, “[t]here is a tendency in philsophy to think in terms of large, poorly differentiated categories.” This tendency might be curtailed by input from the cognitive brain sciences.

3. HOW BRAINS BUILD BORDERS

3.1. STRAWSON ON PERSONS

Strawson (1959) poses two questions concerning personhood. The first question is: “why are one’s states of consciousness ascribed to anything at all?” The second question is: “why are [states of consciousness] ascribed to the very same thing as certain corporeal characteristics, a certain physical situation, &c.?” Strawson believes that the answer to both questions lies in the logical primitiveness of our concept of persons.

Strawson believes that the answer to the second question is simpler, so he gives it first. States of consciousness are only ascribed to persons, and it turns out that persons are also the kind of thing to which it is appropriate to ascribe physical predicates. Strawson believes that attempts at further decomposition are inevitably fruitless, because persons are the most basic concept to which psychological predicates are applied. The contents of our ontology do not include an entity that can be the subject of psychological predicates but not physical predicates. Such an entity, a pure ego, could not be a concept that we possess.

The answer to first question is a little more tricky. Strawson appeals to the logical form of predicate application, which requires that a predicate be contingently applicable to more than one individual. A predicate which is only applicable to one target, may as well apply to none at all: if it is true that the target possesses said predicate, it is a tautology to state that the target possesses it. In the case that the target does not possess the predicate, the predicate could have no place in any discussion, as it is never possessed by anything. It is thus a necessary condition of applying psychological predicates to ourselves that we are first able to apply psychological predicates to others. To apply psychological predicates to others, we must have some way to individuate the targets of psychological predicates. The only targets for which individuation is possible are persons, who have physical, as well as mental, traits. So the answer to the first question is that mental states are ascribed because our primitive concept of persons allows them to be applied to others, as well as to ourselves.

If it holds water, Strawson's argument has implications for psychology. An inability to ascribe psychological predicates to others, would engender an inability to ascribe personhood to oneself and to others. The concept of a person (in the Strawsonian sense) would effectively disappear from the ontology of someone with this disability. This has been borne out by psychological research on 'theory of mind'.

3.2. PERSONHOOD AND 'THEORY OF MIND'

'Theory of mind' is the psychological term for our ability to ascribe others with beliefs and desires, i.e., the ability to ascribe others with psychological predicates. People with autism display behaviour that is explainable in terms of a non-functioning theory of mind. In experimental studies, autistics have been shown to perform poorly on tasks that involve reasoning based on the attribution of mental states, while performing at a normal level on tasks that involve other kinds of inference. Autistics do significantly worse than healthy controls on what is called a 'false belief' task. A typical false belief task pairs a story with a question about what one of the characters in the story believes to be the case.

An example story (from Sabbagh & Taylor, 2000):

Ben put a folder and a clipboard on his desk.
His friend Maggie noticed that he had lots of work to do.
Then, Maggie went out for a coffee.
While Maggie was gone, Ben moved the clipboard.

Ben put the clipboard on the bookshelf.
He left the folder on his desk.

This is paired with the question:

According to Maggie, where is the clipboard?

The correct answer is, of course, that Maggie (mistakenly) believes that the clipboard is on the desk. We know this because she was not in the room when Ben moved the clipboard, and could not have knowledge of the change. If autistics are not able to attribute others with any beliefs, mistaken or not, it would explain their difficulty with this kind of reasoning.

This can be contrasted with ‘false photograph’ tasks. Autistics have no trouble understanding that states of the world can be represented by photographs. Answering questions about stories in which photos represent counterfactual states of the world, is not a problem for autistics. They are able to perform at the same level on these tasks as everyone else.

To say that autistics live in a solipsistic world understates the case: not only are autistics cut off from understanding the mental lives of others, they are unable to recognize their own.

3.3. DRAWING THE BOUNDS OF REASON

Deficits in ‘theory of mind’ reasoning co-occur with pathological conditions other than autism. Damage to particular brain areas caused by stroke, trauma, or congenital defect has been observed to induce deficits similar to those found in autistics. Evidence from these lesion patients, and from functional neuroimaging studies on healthy subjects performing theory of mind tasks, indicates that theory of mind utilizes a dedicated neural substrate, and is a localisable neurophysiological module. The invariance of the development of theory of mind in children points towards a genetically pre-determined component to this module.

If theory of mind turns out to be innate, it could be seen as empirical evidence for the primitiveness of the concept of person. The functional specifications of what such a module must be like are laid out in Strawson’s explication of persons: such a module must allow us to attribute states of consciousness to a single entity to which we also attribute physical characteristics, and states of consciousness must also be attributable to others on the basis of behavioural criteria. The theory of mind module will be uncovered as fulfilling these specifications or not. If it does not, then the issue of how we conceptualize personhood can be reopened and re-examined in light of the actual operational characteristics of the theory of mind module.

I believe, however, that the theory of mind module will fulfill Strawson's specifications for its operation. This would allow for a different kind of interaction between philosophy and cognitive neuroscience; one in which *a priori* considerations of ontological structure are found to be confirmed or disconfirmed by the cognitive brain sciences.

The bounds of human experience are amenable to investigation by both the cognitive brain sciences, and by philosophy. Philosophy is able to define the *a priori* limitations of mind, leaving the cognitive brain sciences to explain how the limitations could be contingently realized in the brain. While this kind of research is based squarely in the materialist camp, it is important to remember that the method described points only to the *possibility* of such an identity; i.e., *if* it were the case that mind were the same as brain, then the limitations of mind could be explained by some neurological, or computational, constraint on brain function.

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Appendix A

Recall Scores of Individual Subjects. Data Analysis Summary Tables.

Number of Word Pairs Correctly Recalled by Individual Subjects

from the SR (Semantically Related) and nSR (Semantically Unrelated) V-N, N-N and V-V Lists

WORD PAIR CATEGORY

SEMANTIC RELATEDNESS

	Verb-Noun	**Noun-Noun**	**Verb-Verb**
Absent (nSR)	5	6	2
	8	7	5
	4	4	3
	8	6	2
	2	1	1
	8	7	4
	4	5	3
	3	7	4
	4	4	1
	5	8	3
	4	4	2
	5	6	6
	8	6	0
Present (SR)	5	7	3
	7	8	6
	7	10	6
	8	7	5
	6	8	3
	5	6	5
	9	10	7
	6	7	5
	8	6	4
	10	10	8
	4	6	5
	8	6	4

Table 1.

Average Recall Scores for SR-Treated, nSR-Treated and All Subjects

for V- N, N-N and V-V Word-Pair Lists

		WORD PAIR CATEGORY		
	-	Verb-Noun	Noun-Noun	Verb-Verb
SEMANTIC RELATEDNESS	Absent (nSR)	5.2	5.5	2.8
	Present (SR)	6.9	7.6	5.1
	All Subjects	6	6.5	3.9

Figure 1.

Graph Showing Average Recall Scores for SR-Treated and nSR-Treated Subjects

for V- N, N-N and V-V Word-Pair Lists

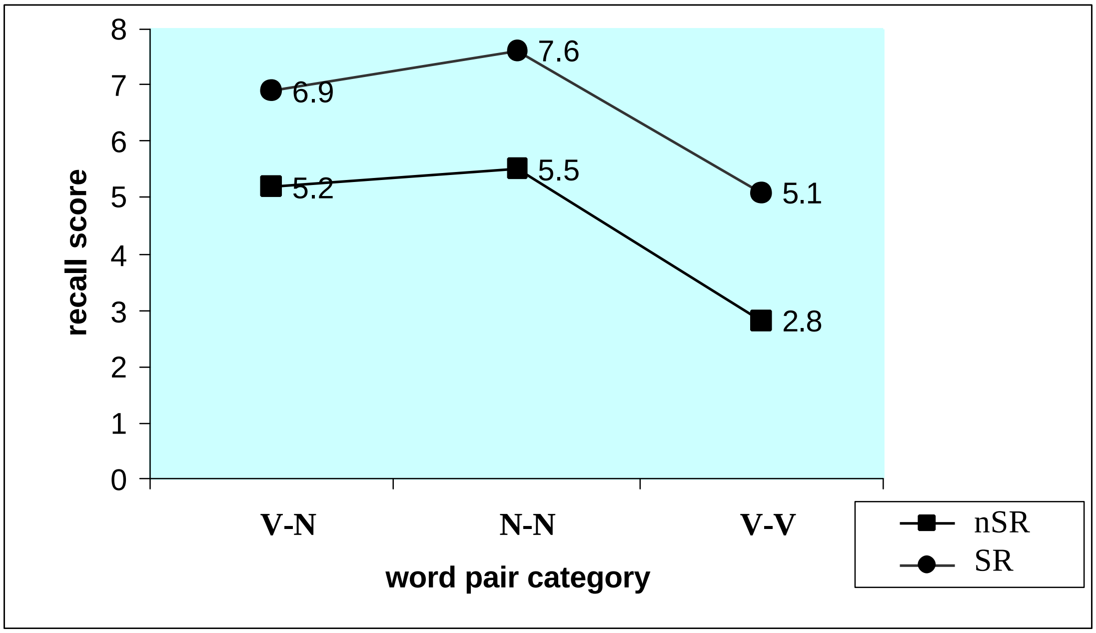

Table 2. Average Scores, Standard Deviation and Number of Subjects

Word Pair Category	Semantic Relatedness	Mean	Std. Deviation	N
Verb-Noun (V-N)	**nSR (absent)**	5.2	2.1	13
	SR (present)	6.9	1.8	12
	total	6.0	2.1	25
Noun-Noun (N-N)	**nSR (absent)**	5.5	1.9	13
	SR	7.6	1.6	12
	total	6.5	2.0	25
Verb-Verb (V-V)	**nSR (absent)**	2.8	1.7	13
	SR (present)	5.1	1.5	12
	total	3.9	2.0	25

Table 3. Factors Effecting the Dependent Variable

	FACTORS	LEVELS
Within-Subject Factor	Word Pair Category	V-N N-N V-V
Between-Subject Factor	Semantic Relatedness	SR (present) NSR (absent)

Table 4. ANOVA: Tests of Average Within- and Between-Subjects Effects

	Source	Df	Mean Square	F	p
WITHIN-SUBJECTS EFFECTS	**Word Pair Category**	2	48.06	29.393	0
	Word Pair Category x Semantic Relatedness	2	0.646	0.395	0.676
	Error	46	1.635		
BETWEEN-SUBJECTS EFFECTS	**Semantic Relatedness**	1	77.951	12.681	0.002
	Error	23	6.147		

Appendix B

Materials.

Lists of Word Pairs Used in the Experiment.

Alphabetical List of Concrete Nouns of High Frequency.

Alphabetical List of Action Verbs of High Frequency.

Lists of Word Pairs Used in the Experiment:

SR (semantically related) V-N (Verb-Noun) List

climb – mountain
eat – cereal
play – game
drink – whiskey
win – medal
wear – helmet
cut – cedar
take – pill
read – letter
drive – car

Lists of Word Pairs Used in the Experiment:

nSR (semantically unrelated) V-N (Verb-Noun) List

climb – hand
eat – needle
play – statue
drink – boat
win – cotton
wear – trailer
cut – crystal
take – sheep
read – parent
drive – eye

Lists of Word Pairs Used in the Experiment:

SR (semantically related) N-N (Noun-Noun) List

tree – forest

street – road

fruit – apricot

chair – table

river – water

father – mother

dollar – money

rose – flower

college – university

cat – animal

Lists of Word Pairs Used in the Experiment:

nSR (semantically unrelated) N-N (Noun-Noun) List

tree – dog
street – heart
fruit – cigarette
chair – ship
river – bus
father – plant
dollar – athlete
rose – stone
college – wheel
cat – pickle

Lists of Word Pairs Used in the Experiment:

SR (semantically related) V-V (Verb-Verb) List

murder – kill
recall – remember
hear – listen
break – destroy
let – allow
increase – grow
protect – cover
start – begin
save – keep
make – build

Lists of Word Pairs Used in the Experiment:

nSR (semantically unrelated) V-V (Verb-Verb) List

murder – ask

recall – become

hear – sell

break – compare

let – unite

increase – draw

protect – describe

start – expect

save – touch

make – forget

Alphabetical List of Concrete Nouns of High Frequency

A	
1	alcohol
2	anchor
3	animal
4	apartment
5	apricot
6	athlete
B	
7	baby
8	balloon
9	bandage
10	barrel
11	basketball
12	bed
13	bird
14	blood
15	boat
16	body
17	bomb
18	book
19	box
20	boy
21	brother
22	bubble
23	bucket
24	building
25	bus
C	
26	cabin
27	campus
28	canal
29	canoe
30	car
31	carrot
32	cat
33	cattle
34	cedar
35	cell
36	cement
37	cent
38	cereal
39	chair
40	child
41	church
42	cigarette
43	citizen
44	city
45	clothes
46	cloud
47	coal
48	coat
49	coffin
50	college
51	cotton
52	country
53	court
54	crystal
55	curriculum
56	custard
D	
57	daisy
58	dancer
59	dentist
60	doctor
61	dog
62	dollar
63	donor
64	door
65	dresser
66	drug
E	
67	earth
68	emerald
69	engine
70	eye
F	
71	family
72	farm
73	father
74	ferry
75	finger
76	fish
77	floor
78	flower
79	food
80	football
81	forest
82	fruit
83	furnace
G	
84	game
85	garden
86	gas
87	girl
88	glass
89	gold
90	government
91	grass
92	gravy
93	gun
94	guy
H	
95	hair
96	hand
97	harness
98	hat
99	heart
100	helmet
101	hole
102	home
103	horse
104	hospital
105	house
106	human
I	
107	ice
108	infant
109	insect
110	island
J	
111	job
K	
112	kid
113	king
114	kitchen
L	
115	lady
116	lantern
117	leaflet
118	letter
119	lobster
M	
120	magazine
121	man
122	mansion
123	map
124	maple
125	marble
126	marijuana
127	meadow
128	medal
129	meat
130	milk
131	missile
132	money
133	monkey
134	moon
135	mother
136	mountain
137	mouth
138	muscle
139	mustard
N	
140	napkin
141	nation
142	neck
143	needle
144	nephew
145	newspaper
146	nose
O	
147	ocean
148	office
149	oil
P	
150	painter
151	paper
152	parade
153	parent
154	pasture
155	penis
156	people
157	person
158	pickle
159	picture
160	pigeon
161	pill
162	plant
163	prairie
164	president
165	puppy
Q	
R	
166	rabbit
167	rice
168	river
169	road
170	rocket
171	rose
172	rope
S	
173	salt
174	sand
175	school
176	sea
177	sheep
178	ship
179	shovel
180	silver
181	singer
182	sister
183	skin
184	sky
185	skyrocket
186	sophomore
187	son
188	spider
189	statue
190	steel
191	stomach
192	stone
193	street
194	student
195	sun
196	sunset
T	
197	table
198	tank
199	teacher
200	teeth
201	timber
202	toilet
203	trailer
204	tree
205	troop
206	truck
207	tulip
U	
208	university
V	
209	valley
210	village
211	vinegar
212	violin
W	
213	walnut
214	water
215	wheel
216	whiskey
217	wife
218	wind
219	window
220	wine
221	woman
222	wood
X	
Y	
Z	

count: 222 words

Alphabetical List of Action Verbs of High Frequency

A		**39**	drop	**72**	measure	**108**	stop
1	accept	**E**		**73**	move	**T**	
2	allow	**40**	eat	**N**		**109**	take
3	ask	**41**	enter	**O**		**110**	teach
B		**42**	enjoy	**74**	order	**111**	tell
4	bear	**43**	expect	**P**		**112**	touch
5	beat	**44**	explain	**75**	pass	**113**	transfer
6	become	**45**	express	**76**	pay	**114**	try
7	begin	**F**		**77**	perform	**115**	turn
8	break	**46**	feed	**78**	pick	**U**	
9	bring	**47**	fight	**79**	play	**116**	unite
10	build	**48**	fill	**80**	practice	**117**	use
11	buy	**49**	find	**81**	produce	**V**	
C		**50**	follow	**82**	protect	**W**	
12	carry	**51**	forget	**83**	provide	**118**	waste
13	catch	**G**		**84**	pull	**119**	wear
14	cause	**52**	get	**85**	put	**120**	win
15	change	**53**	give	**Q**		**121**	write
16	charge	**54**	go	**R**		**X**	
17	check	**55**	grow	**86**	raise	**Y**	
18	choose	**56**	guide	**87**	reach	**Z**	
19	climb	**H**		**88**	read		
20	come	**57**	handle	**89**	recall		
21	compare	**58**	hear	**90**	receive		
22	consider	**59**	help	**91**	recognize		
23	consume	**60**	hold	**92**	release		
24	contain	**I**		**93**	remember		
25	control	**61**	increase	**94**	represent		
26	cover	**J**		**95**	return		
27	create	**K**		**S**			
28	cross	**62**	keep	**96**	save		
29	cut	**63**	kick	**97**	say		
D		**64**	kill	**98**	see		
30	decide	**L**		**99**	sell		
31	decrease	**65**	lead	**100**	send		
32	describe	**66**	leave	**101**	share		
33	destroy	**67**	let	**102**	show		
34	develop	**68**	listen	**103**	sing		
35	divide	**M**		**104**	solve		
36	draw	**69**	make	**105**	spend		
37	drink	**70**	mark	**106**	spread		
38	drive	**71**	marry	**107**	start		

count: 121 words