The Effect of Word Relatedness on Individual Response Time: A Lexical Decision Experiment on Undergraduate Students

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ABSTRACT

Information in long-term memory is organised through semantic connections, which aid in retrieving information. Past studies on lexical decision tasks show that word relatedness affects reaction times. The current research hypothesis builds on those prior findings, suggesting that pairs of real related words are identified faster than pairs of real unrelated words. A total of 274 undergraduate students participated in 48 trials administered through the PsyToolkit Program, comparing related and unrelated word pairs that were presented randomly. Participants were instructed to judge a pair of letter strings Results showed faster reaction time for related words (M = 731.26, SD =108.14) compared to unrelated words (M = 765.91, SD = 123.33) with a statistically significant difference in reaction time (W = 9331, Z = -6.98, p < .001). These findings support previous research and suggest practical applications in language diagnostics and education. Future studies should focus on selective sampling and additional variables.

Keywords: *Lexical Decision Task, Reaction Time, Word Relatedness*

ABSTRAK

Informasi dalam memori jangka panjang terorganisir melalui koneksi semantik, yang membantu dalam pengambilan informasi. Studi-studi sebelumnya tentang tugas keputusan leksikal menunjukkan bahwa keterkaitan kata memengaruhi waktu respons. Hipotesis penelitian ini dibangun berdasarkan temuan-temuan sebelumnya, yang menyatakan bahwa pasangan kata nyata yang berhubungan diidentifikasi lebih cepat daripada pasangan kata nyata yang tidak berhubungan. Sebanyak 274 mahasiswa sarjana berpartisipasi dalam 48 percobaan yang dilaksanakan melalui Program PsyToolkit, yang membandingkan pasangan kata terkait dan tidak terkait yang disajikan secara acak. Partisipan diminta untuk menilai pasangan rangkaian huruf. Hasil penelitian menunjukkan waktu respons yang lebih cepat untuk kata terkait (M = 731.26, SD = 108.14) dibandingkan kata tidak terkait (M = 765.91, SD = 123.33), dengan perbedaan waktu respons yang signifikan secara statistik (W = 9331, Z = -6.98, p < .001). Temuan ini mendukung penelitian sebelumnya dan menunjukkan aplikasi praktis dalam diagnostik bahasa dan pendidikan. Penelitian di masa depan harus fokus pada sampling selektif dan variabel tambahan.

Kata Kunci: *Tugas Keputusan Leksikal, Waktu Respons, Keterkaitan Kata*

INTRODUCTION

Human long-term memory comprises the accumulation of knowledge and experience acquired throughout life. The collection of knowledge with no relation to individual historical moments in long-term memory is organised in the form of semantic connections that reside in individual semantic memory (Balota & Coane, 2009). Moreover, studies have conducted experiments to understand the process of organising long-term memory and retrieval of information through lexical decision tasks, particularly focusing on the role of semantic processing in word recognition. Results of such studies indicated the influence of word relatedness in the speed of recognition.

The study on the lexical decision task was originally conducted by Meyer and Schvaneveldt (1971) which aimed to further investigate the impact of meaning on lexical decisions. The study comprised two experiments and recruited 12 high school students who served as paid volunteers. In the first experiment, participants were presented with a pair of letter strings and instructed to judge whether both strings were real English words or not. Results from this first experiment found that responses were faster for commonly related words than unrelated words. Meyer and Schvaneveldt's (1971) findings suggested that there is activation of linked concepts in our long-term memory that impacted the speed of retrieval of information. Despite that, the sample size in this study was relatively small, limiting the reliability and generalisability of the result.

Meyer and Schvaneveldt's (1971) research were later supported by a similar study conducted by Fischler (1977). In the experiment, the participants were 24 undergraduates at the University of Florida who took part in the introductory psychology course. The method was similar to the previous study where participants were instructed to judge whether both letter strings were words and to respond as quickly as possible. However, Fischler (1977) expanded the study by providing four conditions of word pairs: two related word conditions (associated related and semantic related) and two control conditions (unrelated and non-word) and each participant was shown half of four types of pairs of letter strings. Faster responses were detected in both associated and semantically related word pairs compared to the corresponding control pairs, with semantically related demonstrating greater facilitation in recognition than those related by association. The expansion of experimental conditions in this research could provide deeper insight in regards to the mechanism or processes of information storage and retrieval. However, the current study also had a relatively small sample size which may limit its generalisability.

More recent studies on the relationships between semantic relatedness and response speed were conducted by Rataj et al. (2023) in Poland. The experiment employed the lexical decision task, but utilised Polish words instead of English which introduced a different variation. Additionally, the study provided three semantic priming conditions which include strongly related, weakly related, and semantically unrelated word pairs. The participants were 72 first-year bachelor students at the Faculty of English, Adam Mickiewicz University in Poznań who were native speakers of Polish. They were randomly assigned to one out of six sets of study and each completed a total of 288 trials, with 108 trials being experimental trials. Despite linguistic differences, Rataj et al. (2023) study demonstrated consistent findings to past studies where response speeds were the fastest for strongly related word conditions and the slowest for unrelated word conditions. The research indicated semantic processing universality beyond linguistic boundaries and potential generalisability increase due to its larger sample size.

Previous research has demonstrated consistent outcomes regarding word relatedness influences on the facilitation of word recognition which impact individuals' time in identifying words. The objective of this study is to demonstrate that semantic relatedness influences reaction times, specifically showing that semantically related words are identified more quickly than unrelated words. By producing evidence that validates and extends previous research on semantic relatedness and reaction times, the study aims to provide reliable, generalizable data that enhances our understanding of how semantic relatedness impacts cognitive performance across a broader population. Furthermore, the

study seeks to offer suggestions for practical applications of its findings in various fields, including education, language processing, and cognitive neuroscience. Based on the analysis of past findings, it is hypothesised that pairs of real related words are identified faster than pairs of real unrelated words.

METHOD

Research Design

The experiment employed quantitative experimental research with a within-subject design. Experimental research involves manipulation from one or more independent variables and measurement of the effect of dependent variables which allow for the determination of casual relationships in this context. Additionally, employing a within-subject design allows for direct comparison within the same individual which controls for biases and reduces the variability due to individual differences. This design ensures each responses are measured consistently across different conditions relative to their baseline, rather than comparing across different individuals. Additionally, the within-subject design allows maximising the use of available participants, especially when there are limited participants or when there are restrictions to the sampling.

The independent variable in this study was real English words with two levels of conditions: related and unrelated word pairs and each participant was exposed to both. The dependent variable was the participants' reaction time in judging related and unrelated real words, measured through the time elapsed between the stimulus presentation and the participant's button press. As a control measure, two conditions were added to the experimental design: real word-nonword pairs and nonword pairs. Participants completed a total of 48 trials, with 12 trials per condition that were presented randomly in a single block.

Participant

Participants were 274 undergraduate students, with 79.5% women (n = 218) and 20.4% men (n = 56), enrolled in the PYB204: Perception and Cognition class at Queensland University of Technology. Participants were selected using a convenient sampling method and no selection criteria were applied for experiment participation. Participants' age was not recorded.

Measurements

The experiment utilised the PsyToolkit Program (Stoet, 2010; Stoet, 2017). PsyToolkit Program is a versatile free online platform that researchers and students often utilise for conducting psychological research projects or experiments and collecting relevant quantitative data. PsyToolkit Program is equipped with a wide range of abilities, from creating simple questionnaires to interactive complex cognitive tasks. The standard PsyToolkit templates were customised to include additional items relevant to the study's objectives to enhance the results' reliability. Additionally, while the primary focus of this study is on reaction time, accuracy data were also collected and shown in the result at the end alongside reaction time. This was done to ensure task engagement and to provide additional context for interpreting the reaction time results. However, the primary analyses and conclusions will be based on reaction time data.

In this study, the PsyToolkit program was used to present the participants with an interactive cognitive task where a pair of letter strings is presented in each trial. It then displays the accuracy and the

reaction time of the participant. Participants then manually input the result to Microsoft Excel where they also input their initial and gender to collect demographic data.

Data Analysis

The data in this study were analysed using descriptive statistics and inferential statistics techniques to test the hypothesis. Descriptive statistics were utilised to summarise each condition's reaction times and accuracy rates. The means, standard definitions, and confidence interval were calculated to give an overview of data central tendency and variability. Normality assumptions were assessed using the Shapiro-Wilk test. Additionally, the Wilcoxon signed-rank test, a non-parametric inferential statistics method, was also performed to compare the reaction times between related and unrelated real word conditions.

The data analysis was performed using JASP, version 0.19.1. JASP was chosen due to its user-friendly interface, which simplifies the analysis process, and its ability to conduct both basic and advanced statistical analyses. The software is particularly well-suited for handling both parametric and non-parametric tests, providing clear visualisations and easy-to-interpret results. Additionally, JASP's open-source nature and its integration of modern statistical techniques make it an ideal choice for conducting robust and accurate data analysis.

RESULTS

A within-group analysis was performed on the data. The descriptive analysis for participants' reaction time, measured in milliseconds between the shown stimulus and participants' clicks, in related real words and unrelated real word conditions was displayed in Table 4.1. Results from the analysis indicated that participants demonstrated faster reaction time in related real words (M = 731.26, SD =108.14, 95% CI = [718.37, 744.14]) compared to unrelated real words (M = 765.91, SD = 123.33, 95% CI = [751.21, 780.60]). The standard deviation of reaction time in both conditions indicated a low variability in participants.

Table 4.1
Descriptive Statistics for Reaction Time (ms)

Conditions	*M (SD)*	*95% CI*
Related real words	731.26 (108.14)	[718.37, 744.14]
Unrelated real words	765.91 (123.33)	[751.21, 780.60]

Note. M = mean; *SD* = standard deviation; *CI* = confidence interval

Before conducting the inferential statistics, the assumption of normality was checked through Shapiro-Wilk. The results show assumption of normality was not met (p < .05) for both conditions. Therefore, the Wilcoxon signed-rank test was utilised. Analysis through the Wilcoxon signed-rank test on related real word and unrelated real word conditions revealed that there was a highly statistically significant difference in reaction time between related real words and unrelated real

word conditions, W = 9331, Z = -6.98, p < .001. The effect size that was measured through the rank-biserial correlation was -0.490, which indicates a large negative effect. This result suggests that participants whose reaction times are faster in related real word conditions tended to have slower reaction times in unrelated real word conditions.

DISCUSSION

The current study explored individual reaction time in two conditions: related real words and unrelated real words. The results presented support the proposed hypothesis that related words are identified faster than unrelated words. The findings demonstrated consistency with past studies suggesting that semantic or associative relationships between words facilitate faster lexical decision-making processes.

The descriptive statistical analysis showed participants' reaction time in both conditions with faster response speed for related word pairs compared to unrelated words. The increased mean response time for unrelated words suggests greater latency in processing the sets of semantically unrelated words. Moreover, these results indicated that relatedness between words significantly influences individual reaction speed with faster response for related words. Additionally, the higher standard deviation for unrelated real word conditions compared to related real word conditions indicates greater variability in participants' responses. This increased variability may be attributed to the cognitive load associated with processing words that lack clear semantic or associative links, which can make the task more demanding and result in a wider range of reaction times across participants.

The assumption of normality was not met which is a common characteristic in cognitive reaction time studies (Bosch et al., 2019). Given the violation of the normality assumption, a Wilcoxon signed-rank test was conducted. The analysis confirmed a highly statistically significant difference in reaction times between the related real word and unrelated real word conditions. This further demonstrates that participants reacted significantly faster to a pair of related real words compared to a pair of unrelated real words. Moreover, the current findings are consistent with past research (e.g., Fischler, 1977; Rataj et al., 2023) where all reported faster response time on related word pairs compared to unrelated word pairs. This further supports the reliability of the replication and generalisation of the findings.

Additionally, the effect size indicates a large negative effect, suggesting that participants who exhibited faster reaction times in the related real word condition tended to have slower reaction times in the unrelated real word condition. This inverse relationship implies that the two conditions may engage in different cognitive processes or that participants' performance in one condition may be influenced by task-specific factors, such as familiarity or ease of processing.

The possible explanation for this is that the semantic relatedness of the word pair facilitates participants' faster recognition and decision-making. The pair of words that are related in meaning may activate semantic memory networks, and reflect a more automatic or fluent processing, that allows for more efficient retrieval and recognition (Collins, 1988). On the other hand, unrelated pairs of words that lack semantic connection may require more deliberate cognitive effort as participants need to process the word in isolation, which leads to slower reaction time.

Furthermore, this could reflect how semantic memory influences the efficiency of lexical decision-making. Results align with the findings that the activation of related information in individual long-term memory facilitated individual information retrieval (Meyer and Schvaneveldt (1971). Hence, supporting the notion that semantic relationships between words can significantly affect reaction times and may point to deeper cognitive mechanisms involved in word recognition.

CONCLUSION

Overall, word relatedness plays a significant role in reaction times during lexical decision tasks, with participants reacting faster to related real words compared to unrelated word pairs. This supports the hypothesis that semantic connections between words facilitate faster lexical decision-making. The findings are consistent with previous research, confirming that related words activate semantic memory networks, enabling quicker recognition and decision-making. In contrast, unrelated word pairs required more cognitive effort, resulting in slower reaction times, which highlights the role of semantic relatedness in lexical processing. These results not only validate and expand upon prior research but also provide reliable and generalisable data that enhances our understanding of how word relatedness impacts individual reaction time.

Future research could benefit from using a more selective sampling method with clear criteria to ensure diverse characteristics, such as demographic factors and cognitive abilities, are represented. Recruiting only native speakers, as done in Rataj et al. (2023), could improve accuracy and validity, especially in tasks involving the participants' native language. Additionally, investigating the impact of word length on reaction times, given the mixed results in previous studies (e.g., Forster & Chambers, 1973; Chumbley & Balota, 1984), would provide valuable insights. Controlling the order of word presentation is also recommended to minimise potential confounding effects. In terms of practical applications, the findings could assist in assessing and diagnosing language disorders and cognitive impairments, as well as in developing rehabilitation tasks or programs for individuals with such conditions. Furthermore, tailored language learning tools or cognitive training programs could be created to improve reading fluency and comprehension, particularly for second-language learners.

DECLARATION OF POTENTIAL CONFLICT OF INTEREST

Zahra Rizqi Putri Fatiha and Pramesti Pradna Paramita do not work, serve as consultants, hold shares, or receive funds from any company or organisation that may profit from the publication of this manuscript.

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