The Effects of Cognitive Stress on Lexical Retrieval

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Abstract

This paper aims to examine how stress affects the rate of lexical retrieval of stress-related words. This study conducted a series of lexical decision tasks performed under controlled, minor stress-inducing and major stress-inducing conditions. A statistical analysis of the results revealed that, under regular conditions, stress-inducing words did not significantly accelerate the retrieval of other stress-related words. However, all prime types were retrieved significantly faster while under major levels of stress and this effect was most pronounced for the stress-related words. These results present an additional argument for a non-modular approach to the structure of the mind as in a modular approach there would be no expected interaction between increased levels of stress and accelerated lexical retrieval as it would be assumed that their respective systems operate independent of each other. Additionally, a closer inspection of the participant data from the minor-stress condition revealed that words which had been considered to be very stressful were retrieved at a faster rate than the remaining stress-related words. This would reinforce the suggestion that relatedness is a continuous variable and could suggest that stress-related words do prime other stress-related words provided that the intensity of stress associated with any two lexical items is strong enough.

Keywords attachment theory, functional decomposition, item-level priming, lexical retrieval, stress-related priming

1. Introduction

The study of lexical decision making is one of the fundamental links between linguistic theory and attachment theory. These two fields of study have been abundantly theorised and discussed in isolation, but there is still a lack of any substantial analysis regarding a potential overlap between the two—primarily concerning the impact of cognitive stress on language processing. Of the few studies that have examined how stress affects lexical retrieval, the theoretical concerns have been fundamentally psychological and have concerned themselves with attachment theory (Bowlby, 1973).

According to Bowlby (1973), encountering stress activates the attachment system and, as a result, the individual feels inclined to reach out to supportive figures in their life as a coping action. Mikulincer et al. (2000) build on this by proposing that, as a result of undergoing stress, the attachment system activates proximity-related thoughts which are manifested in a faster rate of lexical retrieval for words that are proximity-related (e.g. mother, hug etc.). This relationship between attachment and proximity themes has been expanded upon and verified by numerous other researchers and studies (Carr & Landau, 2012; Feldman et al., 2004; Mikulincer, Gillath & Shaver, 2002; Baldwin et al., 1993).

While there have been several studies conducted regarding the effects of stress on lexical decision making, these have been primarily psychology studies and, therefore, have largely eschewed close inspection of the relevance of linguistic issues. One such issue was briefly mentioned in the conclusion of Mikulincer et al.'s study where the researchers claimed that stress-relevant words should make accessible stress-relevant thoughts. The present study aims to build on the work of Mikulincer et al. by separating the issue of stress from lexical priming in order to determine whether stressful primes do facilitate the retrieval of other stressful words as well as if this phenomenon is accelerated by the introduction of more severe levels of stress.

By teasing apart some of the effects of stress on lexical retrieval, this study aims to shed some light on the ways in which we access the mental lexicon by measuring how the speed of lexical retrieval is impacted when utilising both the cognitive and linguistic components of the mind. An observed effect could suggest that the cognitive and linguistic components of the mind interact and would argue for some degree of non-modularity; while a failure to observe any significant effect would contribute to the idea of massive modularity (Carruthers, 2006). In addition to the topic of modularity, this paper aims to contribute towards the discussion of lexical decision making by attempting to discern whether stress-related words can be classified as a novel perceptual feature in the mental lexicon.

2. Literature Review

2.1 Lexical Priming Theory

Among the proposed models of lexical access, activation models have been the most popular modes of lexical access (Yelland 1994; Bock & Levelt; 2012; Fodor, 1993). As Morton's logogen model (1969) posits, each lexical entry is represented by a logogen (i.e. a node) which is sensitive to the perceptual features that help to categorise a word, for example, phonological, orthographic or semantic features. When the lexicon receives auditory or visual input containing a feature of a certain word, the activation level of a corresponding word increases. Following this, when a logogen reaches a certain threshold it "fires" which results in the output of said word—be that spoken, written or whether the word is simply being recognised (Morton, 1969; Yelland, 1994).

Furthermore, the nodes that represent lexical items have pathways to other associated lexical items. When a lexical item needs to be accessed, the corresponding node is activated and, subsequently, associated words that are connected to it are also partially activated. As a result, accessing any given lexical item will decrease response times for other connected nodes. An example of this would be when the written form of the word 'oat' is read the lexicon identifies a phonological and orthographic relation to the word 'boat' (among other words), thus increasing levels of activation in that particular node so that when the word 'boat' is presented to the reader it can be recalled faster than normal due to the node already having a high level of activation energy. (Fodor, 1983; Yelland, 1994; Meyer & Schvaneveldt, 1974).

2.2 Types of Priming

Priming can be manifested in numerous ways and, referring back to Morton's logogen model, the perceptual features involved in identifying a word can be expanded to far more than simply phonological, orthographic and semantic features—which have already been thoroughly tested (Meyer & Schvaneveldt 1974; Fischler, 1977; Ferrand & Grainger, 1994). Translation priming (Kirsner et al., 1984; Chen & Ng, 1989) and pictorial priming (Costa, Miozzo & Caramazza, 1999; Alonso, 2012) have also been introduced as novel perceptual features since the discovery of the initial priming effect demonstrated by Morton. An example of translation priming in a Chinese-English bilingual would be the Chinese word for 'cow' priming the English word for 'cow', while also priming semantically related words across languages such the English word 'horse' (Chen & Ng, 1989). The use of pictorial priming is the most recently discovered and an illustration of this would be a picture of a table being presented to the participant which then primes semantic representations of the table such as the word 'chair' (Costa, Miozzo & Caramazza, 1999; Alonso, 2012). Evidently, it has become apparent that numerous perceptual features interact with each other in order to facilitate the retrieval of a certain word and the present study aims to determine if there is scope for a novel perceptual priming feature: stress-related priming.

2.3 The Inconsistencies of Priming

While priming tasks have proved to be relatively reliable, recent studies have reported inconsistencies in even some of the most reliable forms of item-level priming such as semantic and phonological priming. Heyman, Bruninx, Hutchinson & Storms (2018) investigated the reliability of item-level priming effects and found that, while the average semantic priming effect (the overall mean across all items) was clear, the effect on individual priming items was often difficult to predict. For example, 'dog-cat' being semantically primed while 'animal-cat' produced a very little priming effect. This unreliability of item-level priming has also been observed in phonological priming, even in some cases where rhyming words were used (Martin and Jensen, 1988; Peter, Lukatela, & Turvey, 1990). As is indicated by the research, certain inconsistencies when assessing the priming data are to be expected.

2.4 How Does Attachment Theory Relate to Lexical Priming?

Mikulincer et al. (2000) demonstrate that stress-inducing words can be used to prime proximity-related thoughts. However, their suggestion that stress-inducing words can facilitate the retrieval of other stressful words in the same way that semantic or phonological priming can has yet to be tested. As a result, the present study aims to address this issue and will be conducting a series of lexical decision tasks in order to determine whether stress-related priming is analogous with the various perceptual features explained previously. The potential for stress to be considered as a relevant aspect of the mental lexicon is facilitated by Morton's logogen model of the lexicon (1969). His suggestion that logogens are sensitive to the perceptual features which help to categorise a word could also be applied to stress-related priming. As the use of translation and pictorial priming

have emerged as novel perceptual features since Morton's model was established, there could be scope for stress-related features being considered as another potential feature that allows for the facilitation of lexical retrieval.

The primary motivation for Mikulincer et al.'s study (2000) was to investigate attachment theory (Bowlby, 1973). This is a theory proposing that humans activate their attachment system when undergoing stress in order to maintain proximity with significant others in an attempt to regulate said stress. It is thought that the attachment system is manifested in proximity-related thoughts and this study aimed to prime proximity-related thoughts (e.g. mother) by inducing stress and thus activating the attachment system. In order to investigate attachment-proximity themes, Mikulincer et al. (2000) carried out a lexical decision task and hypothesised that, when presented with a stress-inducing prime (e.g. illness), the participant would be able to access proximity-related words (e.g. mother) more easily than they would with other words as a result of the minor stress that they experience while processing this word. The researchers successfully found that participants responded faster to attachment-related words than to any other lexical forms when under stress. Their reasoning for this was that stress arousal activates the attachment system which allows for faster retrieval of attachment-related words. This suggests that cognitive stress is connected on some level lexical retrieval. The present study aims to separate the issue of cognitive stress from lexical priming by determining if, as Mikulincer et al. (2000) suggested in their conclusion, stress-inducing primes facilitate the retrieval of stress-related words as well as whether increasing overall stress levels primes other stressful words.

2.5 The Cases For and Against Modularity

Should the results of this experiment align with the hypothesis, it would suggest that stress is part of the lexical specification of words much like phonology and meaning is. This would suggest that the mental lexicon is radically integrated with other aspects of our cognitive structure and could support the argument for Fodorian modularity (1983) that various components of the mind are fundamentally separate but still interrelated in the sense that they communicate information to each other (Lehmann, 2019). Lehmann describes the implications of Fodorian modularity as language occupying a separate area of the brain to the general cognitive system while also noting that, despite the language module having its own independent neural hardwiring, there exist cross-modular connections between systems.

Fodorian modularity would appear to not only facilitate Mikulincer et al.'s findings regarding the attachment-system (which would form part of the general cognitive system) interacting with the mental lexicon, but it could also justify the introduction of stress as a perceptual feature in the lexicon by demonstrating a concrete connection to the general cognitive system. These cross-modular connections are also discussed in Fodor's (1983) presentation of the modular cognitive system as analogous with Turing machines as he notes that its functional architecture consists of small subsystems that make up the entire cognitive system. Fodor posits the idea of subsidiary systems supplementing the main system (much like a scanner or printer is a supplement to a computer) and the introduction of stress to the workings of the mental lexicon may prove to be one such subsidiary system to language processing, as the general cognitive system would act as an input system to the language module due to the stress being introduced. This could strengthen the case for Fodorian modularity—which is, to a certain extent, non-modular—as it would provide an example of two separate components of the mind interacting with each other despite operating independently and the significance of this is that, thus far, cognitive stress had been deemed to be modularly distinct from the structure of the mental lexicon.

In some versions of modular theory, also known as massive modularity, there have been proposals put forward such as the 'Argument from Computational Tractability' (Carruthers, 2006).

Prinz condenses Carruthers argument for encapsulation—and, therefore, modularity—into three parts. He summarises this argument by claiming that: all computational mental processes must be tractable (i.e. able to be influenced) because the mind is a computer, that these processes are all carried out in a finite period of time, and that if mental processes had access to all the information in the mind then these processes would not be tractable as it would take such a long period of time—possibly years. Carruthers' argument is essentially that mental processes being tractable is only possible in an encapsulated system because if the entirety of the mind could be accessed when conducting mental processes it would take many years. However, according to Carruthers' theory, there should be no expected interaction between stress and the mental lexicon as they are encapsulated in separate modules, and as they are supposedly incapable of interacting there should be no way for one to influence the other.

In contrast to massive modularity, there is the theory of functional decomposition which simply claims that the mind is made up of numerous interconnected systems and sub-systems that are distinguished by the functions that they carry out (Prinz, 2006). There is no mention of modules being informationally encapsulated as functional decomposition is a non-modular approach and one which this study would support should there prove to be any correlation between levels of stress and decreased response times. This would also illustrate a key aspect of functional decomposition in that it allows for numerous input systems to interact. This non-modular architecture would appear to be more akin to Fodorian modularity as opposed to Carruthers' theory due to the potential for cross-modular connections and the comparable view that the mind is a machine made up of component parts (Prinz, 2006; Fodor, 1983).

3. Methodology

3.1 Participants

This experiment utilised 12 undergraduate students ranging in age from 18 to 24 years. This age range was used in order to prevent potential age-related confounds in addition to the convenience of having a large pool of potential participants to select from. The lexical decision task used for this experiment involved two separate tests involving 3 groups of participants with each consisting of 5 participants. These groups included: a control group, a group responding to stress-inducing stimuli (hereafter referred to as the minor-stress condition) and a group that responded to stress-inducing stimuli while kept in a state of constant stress (hereafter referred to as the major-stress condition). The stress-context applied to the latter was achieved by informing the participants that they would be performing a speech following their first experiment as the threat appraisal involved in the speech preparation period leads to increased levels of stress (Feldman et al, 2004).

3.2 Methods and Procedure

In order to determine whether there is a link between differing lexical items that are associated with stress, the present study has adapted the semantic priming paradigm used by Meyer and Schvaneveldt (1971). This involved creating an additional variable than would normally be expected in a lexical decision task. Rather than testing solely for semantic or phonological relations akin to a traditional priming paradigm, the present study tested primarily for whether stress-inducing words would facilitate the retrieval of other stress-related words.

The practice of utilising a priming paradigm to investigate the impacts of stress on an individual has already been established by numerous researchers in attempts to analyse the relationship between stress-related words and attachment-proximity themes (Baldwin et al., 1993; Mikulincer et al., 2000; Mikulincer, Gillath & Shaver, 2002). This research has indicated that the introduction of stress-inducing stimuli facilitates the retrieval of attachment-related lexical items. However, the

framework used for these experiments required some adjustment in order to be able to test for stress-related priming. Rather than using a stress-inducing stimulus to prime an attachment-related word (e.g. death-mother), the present study tested for whether stress-inducing stimuli primed other lexical items with stressful connotations (e.g. death-failure). Much like Mikulincer et al. (2000), in order to determine which words can be classified as stressful, and as a result of the participants being primarily students, the present study gave a sample of students (different to those taking part in the experiment) a word list and requested that they rate the extent of stress associated with each on a Likert scale of 1-6 ranging from 'not at all stressful' to 'very stressful' (see Appendix C). Only those words typically rated 5 and 6 were utilised in the trials initially. However, due to requiring 36 stressful words in total, some of those rated 3-4 were also used to make up the numbers. Of the words remaining that were rated 3-4, only the words with the highest average were selected for the trials.

3.3 Stimuli

In line with the Mikulincer et al. study (2000), each lexical decision trial consisted of a prime being presented for 20ms which was then followed by a pause of 500ms and a target letter string for 1,000ms. If the participant recognised the letter string to be a word they would press the letter 'a' on the keyboard or the letter 'l' if they identified the letter string as a non-word. This was followed by a 2000ms pause before the next trial sequence began.

The trial period consisted of 3 blocks. The first of these was a practice session followed by two blocks—with each of the two blocks consisting of 72 words, for a total of 144 words used throughout the entire trial sequence. The control conditions (delivered to the control group and to the first experiment in the minor-stress condition to act as a baseline) consisted of 24 semantic, phonological, unrelated and non-word pairs each as well as 48 pairs involving a word and a non-word (a sample of the test items can be found in table 1. Alternatively, see Appendix A and B for the prime-target screen and actual word-list).

The following conditions were delivered to the two stress conditions. The semantic, phonological, stress and unrelated pairs were presented in 18 trials each in addition to 24 non-word pairs and 48 pairs involving a word and a non-word. However, before beginning their second block, the participants in the major-stress condition were informed that they had 5 minutes to prepare a short speech to deliver to a panel regarding their time at university which was to be presented after completing their final block. This was done with the aim of triggering a state of constant stress throughout the second block.

For all conditions, the length of strings ranged from between 4 to 8 letters. The non-words were generated by randomly altering a single letter from a real English word. In addition to the experiment stimuli, 18 pairs were used as practice stimuli which involved 4 pairs of semantically and phonologically related words, followed by 5 pairs of non-words and 5 pairs involving a word and a non-word. The selection of semantically and phonologically associated pairs was especially pertinent in order to perform a comparison to stress-related priming and regular unassociated reaction times.

For each trial, the prime word was presented for 20ms as is the standard for subliminal lexical decision tasks (Mikulincer et al., 2000; Mikulincer, Gillath & Shaver, 2002). Subliminal priming was selected over supraliminal priming as this is a well-documented standard in lexical decision tasks related to stress. This is due to its ability to make associated thoughts accessible without necessitating conscious recognition of the word, which could otherwise result in conscious efforts by the participant to alter responses (Mikulincer, Gillath & Shaver, 2002).

Prime	Prime Type	Target	Target Type
Apple	semantic-related	Pear	word
Failure	stress-related	Death	word
Hill	phonological-related	Thrill	word
Hat	unrelated	Food	word
Dace	non-word	Hayr	non-word
Toner	word	Marv	non-word

Table 1: Example of test items.

3.4 Reasoning for Choices of Statistical Analysis

In order to determine whether there was an initial priming effect produced in the control group, a t-test was performed separately on both the semantic and phonological means for reaction times across both experiments. These were compared with the unrelated pairs in order to determine their significance as the unrelated pairs were acting as a baseline throughout the experiment. Similar t-test procedures were carried out in both of the stress-inducing conditions. In the minor-stress condition, participant response times to stress-related pairs were compared with that of the unrelated pairs while the major-stress condition compared response times of stress-related pairs before and after inducing high levels of stress. Conducting these t-tests across all relevant cases helped to establish an accurate assessment of the relationship between regular and stress-induced conditions.

A two-way ANOVA test was carried out across the two experiments for the minor-stress condition in order to determine whether the introduction of stress-inducing words had any influence on the retrieval of other prime types (unrelated, semantic and phonological). A second two-way ANOVA was carried out on the two experiments in the major-stress group in order to determine how all other prime types were affected by the introduction of high levels of stress. Carrying out these ANOVA tests allowed for an accurate estimation of the degree of influence that stress has on the retrieval of lexical items regardless of whether they are stress-related.

3.5 Limitations

While the running of the experiments generally ran smoothly, 2 sets of participant data needed to be eliminated. One was due to their accuracy falling below the 80% accuracy threshold, and another (subject 12) was due to not being performed in fully controlled conditions. The latter was held in a public area with headphones on but continually engaged in conversation with neighbouring parties while also frequently alternating between having their arms crossed and reaching out to respond to the stimuli and assuming the initial position with both fingers on the required keys. This led to largely skewed data and, as a result, this participant's data had to be eliminated from the experiment as only data collected under adequate conditions would be considered for analysis. The reasoning for eliminating subject 12's data is discussed further in the analysis portion of this study.

4. Results and Analysis

4.1 Overview

The aim of this study was primarily to determine if stress played a role in the retrieval of stress-related lexical items. Following on from the work of Mikulincer et al. (2002), this hypothesis supposed that stress-inducing words should prime other stress-related words. There was also scope for determining whether increasing levels of stress further would lead to faster reaction times for said stress-inducing words. In order to determine whether there was a positive correlation between stress and lexical retrieval, the response times were averaged across all 3 conditions (control, minor-stress, and major-stress conditions) with the results detailed below. The following section will present the results of the control, minor-stress and major-stress conditions before investigating individual participant data on a subject-by-subject basis.

As a general rule used in each of the experiments conducted throughout the study, reaction times were analysed only for correct prime-target responses. Only reaction times above 200ms and below 1000ms were considered for analysis, as a result, approximately 10% of overall trial responses had to be discarded across all conditions.

4.2 Control Condition

	Control Condition		Minor-Stress Condition		Major-Stress Condition	
Prime Type	**Experiment 1**	**Experiment 2**	**Experiment 1**	**Experiment 2**	**Experiment 1**	**Experiment 2**
Non-word	784.29	691.74	631.79	633.71	682.43	661.20
Unrelated	**666.47**	**685.81**	**620.88**	**564.63**	**570.88**	**506.84**
Semantic	694.22	602.68	566.45	512.88	516.71	476.44
Phonological	**708.58**	**638.95**	**594.34**	**531.61**	**621.39**	**576.76**
Stress	-	-	-	562.99	526.83	488.43

Table 2: Mean response times across all conditions (ms).

Table 2 contains a summary of the mean response times for all of the conditions conducted throughout the study, separated into the control condition, the minor-stress condition and the major-stress condition. As is evident in the table above, the first experiment in the control condition, somewhat unusually, recorded faster reaction times for the unrelated pairs in comparison to the semantic or phonologically related pairs. However, results appeared to revert to that of the initial expectations during the second experiment as the participants recorded slower reaction times for the unrelated pairs in comparison to the semantic and phonologically related pairs. It is pertinent to note, however, that the average response time for unrelated pairs remained steady at 666ms (experiment 1) and 685 (experiment 2). While the responses to the primed pairs appeared to fluctuate with semantic pairs dropping from 694ms (experiment 1) to 602ms (experiment 2), and phonologically related pairs decreasing from 708ms (experiment 1) to 638ms (experiment 2). As is evident from this data, there was no priming effect present in experiment 1 while there was an apparent priming effect present in experiment 2. This was particularly unusual as a priming effect was expected in both experiments and this may suggest some fault with the

word strings used to elicit this data. Non-word pairs typically recorded the longest reaction time across all conditions while word/non-word pairs were discarded as their purpose was simply to distract the participants.

4.3 Minor-Stress Condition

Table 2 also illustrates the differences between the two experiments for the minor-stress group. Both experiments demonstrated a very clear priming effect as the mean response time for unrelated pairs was noticeably slower than for semantic and phonologically related pairs. While the first experiment was designed solely to act as a control and as a point of comparison, the second experiment introduced stress-inducing words as the unrelated, semantic and phonological pairs all experienced faster response times by approximately 50-65ms. Perhaps most pertinently, the stress-related pairs recorded an almost identical result to the unrelated pairs (562ms to 564ms respectively).

A paired-samples t-test was conducted to compare response times to unrelated words and stress-related words in experiment 2 of the minor-stress condition. There was not a significant difference observed in response times for unrelated ($M=518.5$, $SD=46.05$) and stress-related ($M=506.17$, $SD=41.2$) words; $t(1)=2.056$, $p=0.144$. These results suggest that the impact of stress-related words on the rate of lexical retrieval is not statistically significant.

Following this result, a two-way ANOVA was also carried out on experiments 1 and 2 for the minor-stress condition in order to determine if the stress-inducing words had any discernible impact on the rate of lexical retrieval for other prime types. There was not a significant effect on response times for the assessed conditions [$F(3,16) =0.705$, $p=0.563$]. These results do not suggest that there is a significant impact on response times due to the lingering effect of stress that arises as a result of the presence of stress-inducing words.

4.4 Major-Stress Condition

The results from table 2 also detail how the participants responded to all items (including stress-related pairs) under typical conditions (experiment 1) as well as how this changed with the introduction of greater levels of stress (experiment 2) in the major-stress group. The participants responded to their stimuli, on average, 20-64ms faster in the second experiment while under greater levels of stress. Stress-related pairs experienced a 38ms decrease in reaction times (from 526ms to 488ms). Much like experiment 1 in the control group, the third condition failed to demonstrate phonological priming in either of the experiments as the average response times to the phonologically related pairs exceeded that of the unrelated pairs.

A two-way ANOVA was conducted on the two experiments in the major-stress group in order to determine how reaction time differs across all prime types rather than solely for stress-related pairs. There was a significant effect on the response times due to the increase in stress at the $p<.05$ level for the assessed conditions [$F(1,20) =17.36$, $p=0.00048$]. These results strongly suggest that introducing a stressful situation accelerates the rate of lexical retrieval and that it does have a significant effect on the rate of lexical retrieval for all prime types.

Having observed a notable difference between response times across experiments, something which was confirmed by the two-way ANOVA, a series of t-tests were conducted comparing each prime type across experiments in order to determine how stress affected the retrieval of each prime type. However, the alpha level used to determine statistical significance had to be adjusted as running these 5 t-tests would increase the chance of a type 1 error. Therefore, a Bonferroni correction was applied to the alpha value to be adjusted to $(0.05/5)$ 0.01. There was no significant

difference in the response times for stress-related words when comparing experiment 1 (M=526.83, SD=5.13) and experiment 2 (M=472.43, SD=4.19); t(2)=5.9, p=0.014. These results suggest that there is not a significant difference between the response times to stress-inducing words under normal conditions and response times under stressful conditions at the $p<0.01$ significance level.

As was previously mentioned, stress-related pairs were not deemed to be retrieved significantly quicker under stressful conditions than under normal conditions (p=0.014). Non-words were not found to have a significant difference between experiment 1 (M=682.43, SD=51.44) and experiment 2 (M=646.29, SD=36.98); either t(2)=4.2, p=0.02. There was no significant difference observed between the unrelated pairs in the first experiment (M=570.88, SD=52.95) and the second experiment (M=502.29, SD=67.32); t(2)=2.05, p=0.08. There was also no significant difference observed between the phonologically related pairs in the first experiment (M=621.39, SD=27.79) and the second experiment (M=544.21, SD=26.9); t(2)=2.05, p=0.08. Nor was there a significant difference identified between the semantically related pairs in the first (M=516.71, SD=20.48) and the second experiment (M=470.89, SD=15.96); t(2)=2.78, p=0.06. These results would initially appear to suggest that non-word, unrelated, phonological and semantic related pairs are not retrieved significantly faster while under major stress. However, it must be noted that the Bonferroni correction is quite conservative, therefore, the significant effect demonstrated in the ANOVA can be argued to be originating from the stress-related pairs.

4.5 Individual Analysis

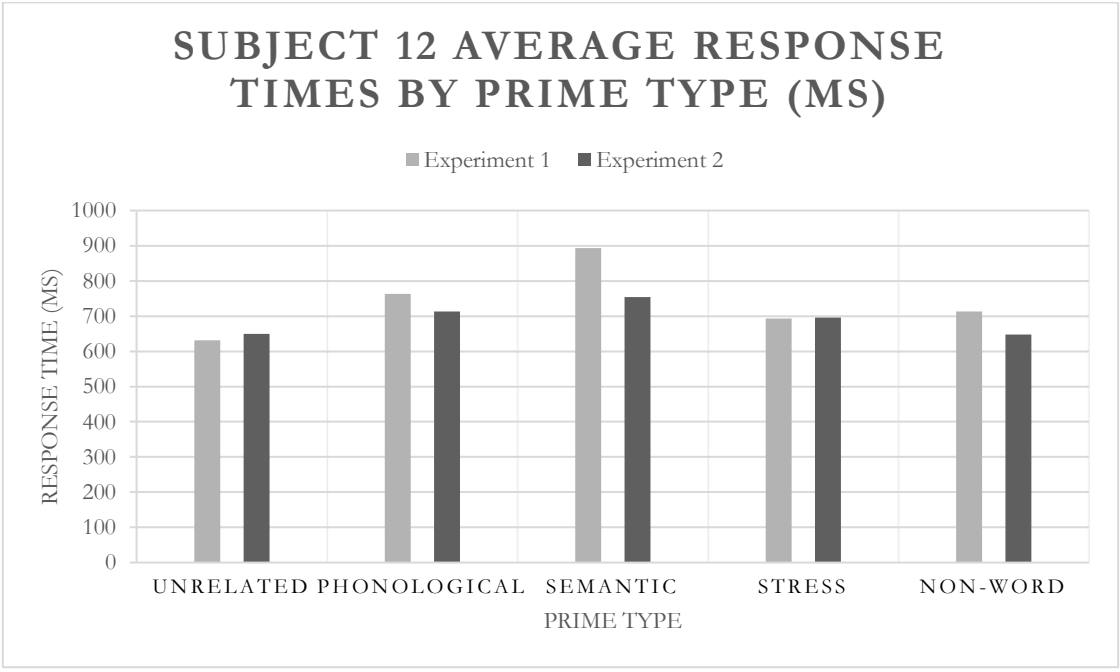

Figure 1: Subject 12 response times.

As was previously mentioned in the limitations of this study (see section 3.5), subject 12's data was compromised and had to be eliminated. subject 12's data is shown in Figure 1 where it can then be compared to the average of the remaining participants' data from the major-stress condition (figure 2). The distribution of data is abnormally skewed in comparison to the average as unrelated and non-word responses were much faster than the traditional priming pairs. Additionally, the standard deviation for subject 12 is larger than expected (113ms and 130ms for each experiment

compared to 94ms and 77ms as the average across participants in this condition). All of the information above taken together leads to the conclusion that this data was compromised and, therefore, must be excluded.

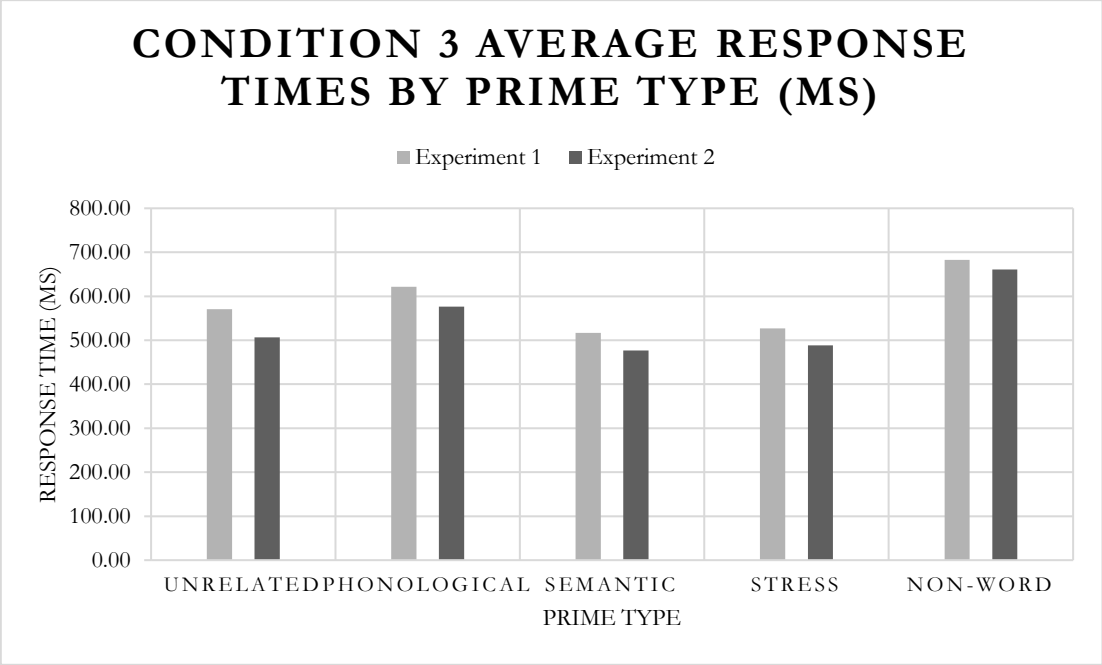

Figure 2: Average response times across major-stress condition.

Having already analysed the average response times across the major-stress condition to determine the effect of additional stress on the retrieval of stress-related words**,** a subject-by-subject observation was deemed to be necessary in order to determine if the variation observed between individuals is similar to that which is observed across individuals. Having already observed skewed figures in the dataset, it was imperative to ensure that it was not one particular individual that was potentially skewing the average. Table 3 clearly illustrates an average response time of 531ms, 527ms, and 521ms for each participant in the first experiment and 483ms, 484ms, and 448ms for the second experiment. This is very clearly in line with the overall average of 526ms and 471ms (figure 2) in the major-stress group. Evidently, there is very little variation between the individuals and this demonstrates that the effect of stress on stress-related words is uniform across participants and not the result of an outlier.

Response times (ms)

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Average**
Subject 9										
Stress (1)	**425**	**505**	**422**	**767**	**528**	**540**	**546**	**552**	**500**	**531.66**
Stress (2)	634	454	461	509	535	516	403	422	419	483.66

Subject 10										
Stress (1)	**602**	**522**	**623**	**393**	**433**	**457**	**511**	**678**	**-**	**527.37**
Stress (2)	579	489	532	451	516	375	483	453	-	484.75
Subject 11										
Stress (1)	**611**	**511**	**731**	**417**	**448**	**495**	**426**	**452**	**602**	**521.44**
Stress (2)	458	450	508	365	397	567	462	384	-	448.87

Table 3: Response times to stress-inducing words across major-stress condition participants.

In a similar manner to the previous example, a subject-by-subject observation of the major-stress condition was required to confirm that there were no data points skewing the overall results and the conclusion that stress-inducing words do not prime other stress-inducing words. The stress-related and unrelated pairs from the second experiment were reviewed and are displayed in Table 4 where subjects 6 and 7 demonstrate typical results when compared against the average displayed in table 2. While subject 5 does appear to take significantly longer to respond to the stimuli, it does not appear to be significant enough to skew the results.

Response times (ms)

	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Average**
Subject 5										
Stress	**884**	**692**	**375**	**637**	**660**	**483**	**918**	**804**	**-**	**681.63**
Unrelated	774	562	565	582	572	522	714	-	-	613
Subject 6										
Stress	**305**	**460**	**520**	**433**	**732**	**584**	**754**	**502**	**443**	**525.89**
Unrelated	423	757	449	439	422	446	600	540	-	509.5
Subject 7										
Stress	**483**	**497**	**373**	**500**	**489**	**517**	**518**	**453**	**548**	**486.44**
Unrelated	446	461	634	554	528	443	517	472	488	504.78

Table 4: Response times to stress-inducing words across minor-stress condition participants.

4.6 Summary of Results

The results and analysis presented throughout this section demonstrate an inconsistent semantic and phonological priming effect in addition to the absence of any significant priming effect pertaining to stress-related words under regular conditions. However, the introduction of major levels of stress does appear to prime all prime types with a particularly noticeable effect on the retrieval of stress-related words.

5. Discussion

5.1 General Discussion

The current findings do not appear to show any significant stress-related priming effect between stress-inducing words. However, the results do demonstrate a clear correlation between greatly increased levels of stress and accelerated rates of lexical retrieval. This discussion will first interpret the data and contextualise this information within previous research and theory before going on to discuss the broader implications of the findings. Finally, this section will end with a review of the limitations of the study before concluding with recommendations for future investigations.

As the correlation between stress-inducing pairs and unrelated pairs in the minor-stress condition was deemed to be insignificant ($t(1)=2.056$, $p=0.144$), the data appears to contradict the proposed hypothesis that stress-inducing words should prime other stress-inducing words. This result differs from Mikulincer et al.'s proposal that stress-inducing words should make accessible stress-related thoughts (2000). However, while there was no reliable priming effect shown for stress-related words even after collapsing the data across all participants, there was a clear observable difference between the unrelated pair averages and certain stress-related word combinations. For example, each participant responded to the 'crime-death' and 'illness-murder' item pairs almost 100ms faster than the average for many of the rest of the stress-related and unrelated pairs. These all happen to be items that scored as 'very stressful' (6) on the Likert scale (1-6) that was presented to a set of students when determining which words could be classified as stressful for the experiment (see Appendix C for a sample of the survey). By contrast, the stress-related items of 'debt-lonely' and 'divorce-virus' all scored as mildly stressful (3-4) which could suggest that there is a certain threshold of stress that must be reached in order for a stress-related word to be primed—much like Morton's logogen model describes (1969).

The observable differences in response times between differing individual stress-related items could reinforce previous findings which have suggested that relatedness is a continuous variable rather than a dichotomous on/off switch (Heyman et al., 2018). The researchers provided an example by comparing response times to the item pairing 'dog-cat' and 'animal-cat' to demonstrate that this continuity is reflected in a larger priming effect for the former pair. Despite both primes possessing some semantic association to the item 'cat', the item 'dog' facilitates the retrieval of 'cat' significantly faster than 'animal' would because it is more strongly associated with the target word, as a result, there would be differing priming effects despite both primes being examples of semantic priming. This could be an effect that has been mimicked in the present study as the words adjudged to be most stressful words were subject to the fastest reaction times which differs from the more mild stressful pairs producing little to no priming effect. If this were the case, it would support Heyman et al.'s findings regarding relatedness being a continuous variable while also reinforcing their stance on the unreliability of item-level priming. While the results of the present study were certainly unexpected, this interpretation of results could be significant in providing the opportunity for stress-inducing words to still be investigated as a potential perceptual feature if more carefully considered stress-inducing words were to be presented to future participants.

One of the most surprising findings of this study was the lack of a consistent priming effect produced in experiment 1 of the control condition for both semantic and phonologically related pairs (see table 2). This result would initially suggest that semantic and phonological priming is misleading. However, in the face of overwhelming evidence from the existing literature, a more plausible explanation is that the present study's implementation of the methodology is flawed which has resulted in the absence of a priming effect in this particular instance. As a result, any findings made in any of the stress-related experiments cannot be considered to be as robust as they otherwise would have been—this is compounded by the fact that neither of the experiments in the major-stress condition demonstrated the effects of phonological priming. Unlike the stress-related priming discussed previously, Heyman et al.'s findings (2018) do not accommodate for this result of failing to observe a priming effect as the data does not show a priming effect even once collapsed. The inconsistencies of priming that the researchers outline only concerns individual item-level primes having a stronger or weaker effect than other individual item-level primes which, in this instance, does not appear to be the case. A t-test was not deemed to be necessary to determine the overall significance of this finding as the overall mean for semantic and phonologically related items far exceeded that of the unrelated.

Despite not achieving a statistically significant result with regards to the primary hypothesis, the data does appear to support the secondary hypothesis concerning whether the introduction of greater levels of stress would facilitate the retrieval of stress-related words. The ANOVA that was conducted on the major-stress group suggested that introducing greater levels of stress would significantly decrease reaction times as this relationship was found to be statistically significant at the 0.05 level ($p=0.00048$). This finding on its own would already suggest that there is a link between the linguistic and cognitive segments of the mind as the introduction of stress was shown to lead to the facilitation of all prime types. This ANOVA demonstrates that there is a significant effect of both prime type ($p=0.0045$) and experiment but with little interaction ($p=0.87$). However, having performed this ANOVA, a series of t-tests still needed to be conducted on each prime type across the experiments in order to determine which prime types were causing this significant effect of experiment. None of the prime-types were deemed to be statistically significant. Although, due to the Bonferroni correction being very conservative, the stress-related pairs ($p=0.014$) can be argued to be the source of the significant effect produced in the ANOVA as opposed to the next closest to the adjusted alpha value (0.01) which was the non-word pairs ($p=0.02$).

This potential relationship between major levels of stress and decreased response times to stress-related pairs, at the expense of the facilitation of the other forms of priming, could advocate for the presence of stress-related priming. If this were true, it would imply that there is an interaction between the cognitive and linguistic components of the mind on some level. More specifically, the fact that only stress-related words can be argued to have been retrieved significantly faster under stress compared to under normal conditions would suggest that the mind being in a state of stress facilitates the retrieval of stress-related words. This interaction between the retrieval of stress-related words and increased levels of stress would have two major implications, the first of which concerns the validity of stress-related priming. From what is known about how priming works, logogens are sensitive to the perceptual features which can help to categorise a word—for example, semantic features—and once a particular node reaches a certain threshold of activation energy it fires (Morton, 1969). The fact that the introduction of stress coincided with the shortened amount of time taken to respond to stress-related words would suggest that the stress-related nodes were primed before firing. In the present study, the decrease in activation energy required for a stress-related word to fire can only be attributed to increased levels of stress as all other factors were controlled for, thus advocating for the presence of stress-related priming. This theory would also be applicable to the results of the minor-stress experiment. While the results of stress-related priming in the minor-stress condition were not deemed to be significant upon being

tested—either due to not using equally stressful words or simply due to the absence of any effect—this finding regarding the introduction of major stress could support the theory discussed earlier relating to stress-related words being primed if there is enough stress being generated. In order for stress to be rejected as a potential perceptual feature, there would have to be no indication that stress-related words can be primed. However, the reality is that no absence of effect was observed, quite the opposite as the retrieval of stress-related pairs was deemed to be facilitated as a result of the introduction of stress.

The second major implication of high levels of stress potentially facilitating the retrieval of stress-related items is regarding the theory of modularity. There are numerous perspectives regarding modularity of mind which range from entirely modular (Carruthers, 2006) to non-modular (Prinz, 2006). In Carruthers' proposal, all mental processes can be influenced externally but not internally by other components of the brain as each individual module is encapsulated and kept separate from other modules meaning that no one module can act as an input for another. Therefore, according to Carruthers, there should be no expected interaction between stress and the mental lexicon as the linguistic and cognitive modules occupy different areas of the brain. The results from the present study, however, argue for some degree of non-modularity as the statistical tests strongly suggest that there is a correlation between increased levels of stress and decreased response times to stress-related lexical items. This would mean that stress is radically integrated with other aspects of our cognitive structure and this is a finding that is simply not supported by the massive modularity model presented by Carruthers. As the results of the present study are not accommodated by Carruthers' modular approach, it follows that the results would support the theory of functional decomposition as proposed by Prinz (2006)—an entirely non-modular approach which allows for the communication of different components of the mind.

The present study's finding that introducing stress can facilitate the retrieval of stress-related words would help to corroborate Mikulincer et al.'s existing work regarding stress-related words priming attachment-related words. The reasoning provided for Mikulincer et al.'s findings was that the increase in stress resulted in the participant wanting to reach out to an attachment figure and this desire for proximity primed the corresponding words in the lexicon. This line of thinking contains some parallels to the present study's explanations of why stress facilitates the retrieval of stress-related words. This is because both studies primed participants in a manner which required an input to the lexicon that is not exclusively visual or auditory as would be expected from a typical semantic, phonological or a pictorial prime. The fact that the mind can, if required, be made to take what is essentially a detour by interacting with an unconventional input system, the general cognitive system, would lend support to Mikulincer et al.'s justification for why stress-related words prime proximity-related words.

5.2 Limitations

While the experiments largely ran smoothly, there have been various limitations to the study as a whole, such as the small sample size and the failure to produce a consistent phonological priming effect. Regarding the former, while the study had initially planned to utilise 18 participants, several of them were unable to attend the data-collection sessions which reduced the pool of participants from 18 to 12. Following this, 2 additional participant datasets had to be eliminated either due to confounding variables affecting their performance or simply due to the participant responses falling below the accuracy threshold of 80%. This small sample size only allowed for 3 participants in each of the stress conditions, thus limiting the generalisability of the results and making it difficult to identify significant relationships from the data.

The reliability of the conclusions drawn from the data is also limited by the fact that there was no reliable phonological priming effect observed in the major-stress group even after comparing

overall mean response times. This impacts the overall aim of the research as the methodology used to elicit the data may have been flawed which could mean that there are potential confounds in other aspects of the experiment. Another possible example of this could be that the stress-related words used in the experiment varied too much on the spectrum of 'mildly stressful' to 'very stressful' which could mean that participant response times to certain prime-types were faster than others. However, the mixture of the intensity of stress-related words used does not allow for a definitive conclusion as to whether stress-related words can be considered as a perceptual feature in priming. Therefore, future studies should consider this and ensure that they undertake a more strict testing process when reviewing which stress-related words to include in the experiment—ensuring that there is no large discrepancy with regards to the strength of stress-related words selected.

5.3 Suggestions for Further Research

It must be emphasised that any findings posited in this study are preliminary and, ultimately, inconclusive. Future studies would need to be carried out in order to be able to verify whether stress can be considered to be a perceptual feature in lexical priming by identifying whether there is a priming effect present in stress-related words when participants are under regular and major levels of stress. This would involve replicating the present study while ensuring that the stress-related words are selected more cautiously. This would also involve determining whether the interpretation that stress-related words are primed while under major levels of stress has any basis as the significance of this interpretation is based on the reasoning that the Bonferroni correction is very conservative. The inconclusive nature of this finding demands further testing in order for the secondary hypothesis that stress-related words are primed when under major levels of stress to be wholly accepted or rejected.

Future studies should also consider evaluating the extent of Heyman et al.'s claims regarding the continuity of relatedness as this was a rather unexpected finding in the present study. Not only would further evidence of this theory provide support for the interpretation that more intensely stressful words prime other intensely stressful words, but it would also shed light on the issue of priming as a whole. Lexical decision tasks are widely accepted as reliable in terms of demonstrating a priming effect and future studies could be conducted in order to determine the extent to which an identifiable priming effect is possible. This would involve, for example, establishing a spectrum of most-commonly semantically associated (e.g. dog-cat) to less-commonly semantically associated (e.g. tiger-cat) items for a set of pre-determined source words. This would enable potential studies to determine whether a stronger priming effect is produced for those words deemed to be more strongly associated with a source word in comparison to those which are not. Such research would shed further light on the reliability of item-level priming by making preparation stages of future lexical decision tasks more efficient and, hopefully, lead to the production of a more accurate and reliable priming effect by minimising potential confounds.

6. Conclusion

The present study initially set out to determine, primarily, whether stress-inducing words would prime other stress-inducing words as well as whether introducing major levels of stress would accelerate this process further. This study has found that, despite initial observations, there was no statistically significant stress-related priming effect produced under regular conditions. However, the study has also identified that the retrieval of all prime types is facilitated by the introduction of stress—with stress-related words experiencing the biggest priming effect. This adds to the body of evidence favouring a non-modular approach to modularity of the mind as the cognitive and

linguistic components of the mind have been shown to interact with each other in the process of lexical retrieval. This is a finding which would appear to reject massive modularity as proposed by Carruthers (2006). The present study may have also demonstrated the unreliability of item-level priming as stated by Heyman et al. (2018), although further research would need to be conducted on the validity of stress-related priming in order to corroborate this claim.

While certain elements of the initial hypothesis have been answered, there remain doubts over the extent to which stress-related words can be primed owing to the varying levels of stressful words used in the present study. Additionally, the lack of a consistent phonological priming effect produced limits the strength of the claims made in this paper as the absence of such a well-established priming effect hints at a potentially flawed methodology. Future studies should aim to replicate the present study while correcting for the errors proposed above which should clarify whether a stress-related priming effect can be consistently produced. There is also scope to determine the extent to which relatedness is a continuous variable as confirming the validity of the claim that priming operates on a spectrum would serve to aid the overall accuracy of lexical decision tasks as a whole.

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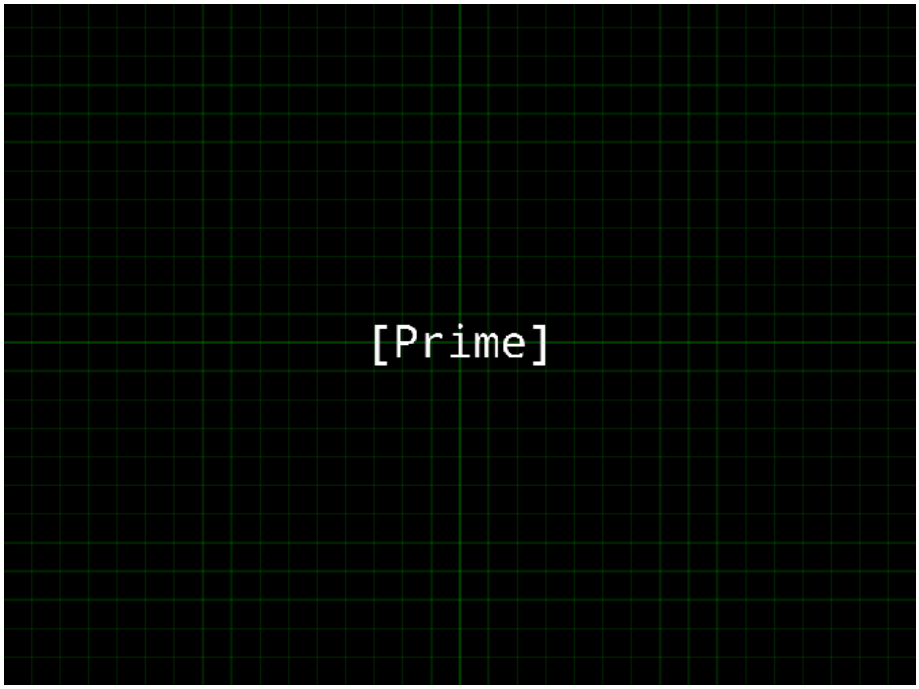
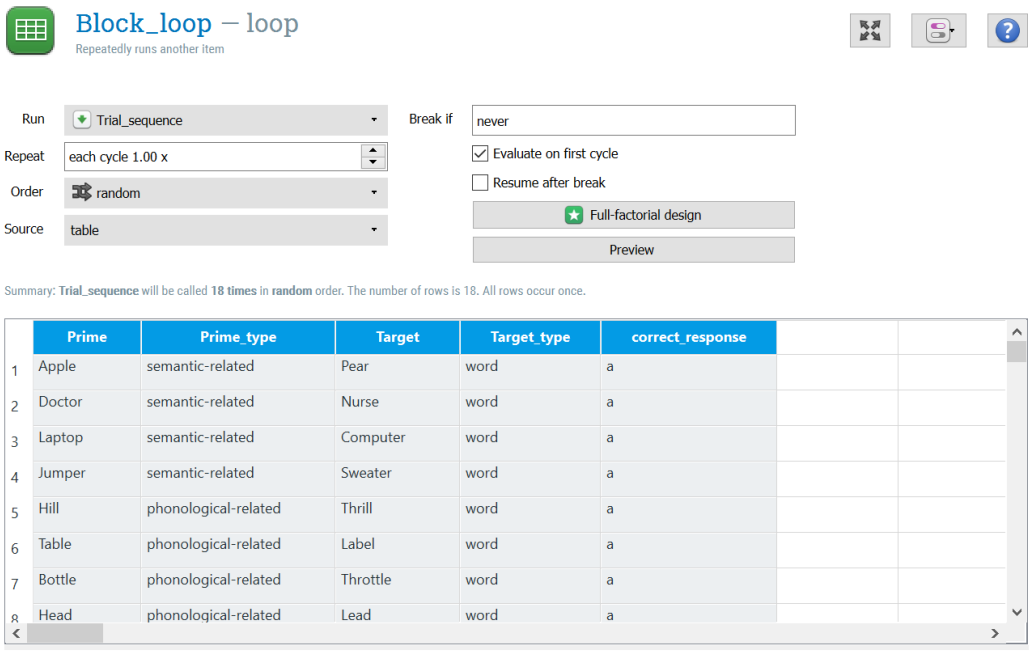
Appendix A: Prime-target screen



Appendix B: Sample word list



	Prime	Prime_type	Target	Target_type	correct_response
1	Apple	semantic-related	Pear	word	a
2	Doctor	semantic-related	Nurse	word	a
3	Laptop	semantic-related	Computer	word	a
4	Jumper	semantic-related	Sweater	word	a
5	Hill	phonological-related	Thrill	word	a
6	Table	phonological-related	Label	word	a
7	Bottle	phonological-related	Throttle	word	a
8	Head	phonological-related	Lead	word	a

Appendix C: Stress-word survey

Please grade the following set of words on a scale of 1-6, with 6 being 'very stressful' and 1 being 'not at all stressful'.

War

1 2 3 4 5 6

Evil

1 2 3 4 5 6

Shock

1 2 3 4 5 6

Illness

1 2 3 4 5 6