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Language Processing in Bilinguals

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Introduction

As bilinguals must constantly negotiate between two potential lexical choices in order to retrieve meaning, the study of bilingualism is an effective way in which to assess the potential modularity or interactivity of language processing. Traxler (2012: 419) asserts that 'the first rule of bilingualism is that the two languages compete', and indeed research has shown that lexical information from both languages is automatically activated before the appropriate language term may be selected (Bailystok et al., 2004). For example, English and German-speaking bilinguals would automatically activate both words 'dog' and 'Hund' when presented with a 'domesticated carnivorous animal' (OED, 2012), but have to ignore the undesirable word choice depending on the context. These interactions are present when a second language is acquired as well as during comprehension and production in capable bilinguals (Kroll & Schwartz, 2006).

There are two models submitted by Potter et al. (1984) to account for this interaction: the Word Association model (WA) and Concept Mediation model (CM), the suitability of which they investigated by having bilinguals of ranging proficiency name pictures and translate words. The WA model proposed that new second language (L2) words would be accessed indirectly after being translated into the existing first language (L1) system, thus for example the German 'Hund' would be immediately identified as the English-dominant 'dog' and bilinguals would perform better on the translation aspect of the study, whilst in the CM model meanings 'dog' and 'Hund' would be accessed directly. Their experiments found that participants named pictures and translated words at approximately the same average speed, indicative of CM. Bialystok (2001: 102), also surmises that the growing body of research including, among other areas, research into Stroop interference, suggests that the two languages are presented independently.

If bilinguals indeed process language by quickly selecting and rejecting conflicting information, they should, in theory, perform better than monolinguals in incongruent examples in the Stroop task (1935), in which participants must verbally identify the colour of a word, whilst resisting the urge to read the word itself. Stroop Interference occurs when the automaticity of reading prolongs the time taken to focus on the colour and produce a reaction, whilst Stroop Facilitation features shorter reaction times (RTs) when the stimuli are presented congruently, for example the word 'RED' written in red ink, and do not feature this conflict (Van Heuven et al., 2011: 1). To overcome the disparity between ink colour and word written, conflict resolution processes and cognitive control is required, skills already utilised by bilinguals to make choices between languages (Van Heuven et al., 2011). As a result, bilinguals are more efficient in executive control tasks, such as Stroop, whilst monolinguals are not inhibited by these constant conflicting lexical choices and perform better in lexical retrieval tasks which bilinguals find more effortful (Bialystok et al., 2008). With their greater level of cognitive control and experience with handling rival information, bilinguals may read words on the Stroop task less automatically than monolinguals and thus be less susceptible to the Stroop effect (Bialystok et al., 2008). Moreover, bilinguals are faster in the Simon task, in which participants must ignore the spatial position of the word and press on a keyboard a button on the left or one on the right to indicate true or false. (Bialystok et al., 2005).

However, although this research is highly supportive of CM, Zhang et al. found that Chinese-English bilinguals translated English words into Chinese in a morpheme lexical decision task (Zhang et al., 2011). When presented with English word pairs whose Chinese translations repeated the first morpheme, reaction times were faster than for words which did not translate into such straightforward morphologically repetitive words, suggesting that bilinguals automatically translate into their L1.

Chinese-English bilinguals exhibit right-hemisphere activation when reading both languages, whilst American students learning to read Chinese later as L2 only demonstrated right-hemisphere activation when reading Chinese characters (Perfetti et al., 2007). Whilst performing the Simon task, magnetoencephalography (MEG) imaging revealed that fast responses in the conflict examples resulted in increased activation in Broca’s area for bilinguals, but in the dorsolateral prefrontal cortex and other frontal areas of monolinguals (Bialystok et al., 2005). Bilingualism also results in denser grey matter in the left inferior parietal cortex and, as Perfetti et al. and Bialystok et al. demonstrate, affects how the brain is structurally organised to accommodate the two languages (Michelli et al., 2004). It is evident therefore that bilingualism and the necessity to suppress undesirable information has a profound effect on the brain and how language is processed.

To personally investigate this conflict bilinguals experience when retrieving a word, I will perform a Stroop task on an equal number of bilinguals and monolinguals. I will show 5 monolinguals and 5 bilinguals the same pattern of 40 colour words on a laptop, record their vocal responses and analyse the reaction time taken to respond to each incongruent word. The Stroop task replicates the process of interference and competition (in this case between the instinct to read the word and identify its colour) experienced by bilinguals, whose conflict occurs between two semantically equivalent words, and thus will be an interesting method of testing a participant’s ability to handle this conflict. By directly comparing the reaction times of the two groups of participants I will be able to find either support for the WA or CM models of bilingual language processing. I expect the results of the experiment to comprise of faster RTs from bilinguals than monolinguals due to their increased cognitive capacity in processing competing word choices, in line with previous studies that have found bilinguals to cope with conflicting information more successfully than monolinguals (Bialystok, 2001; Bialystok et al., 2004; Okuniewska, 2007; Bialystok et al., 2008; Van Heuven et al., 2011). If this is the case, the study is also expected to show support for Potter et al.’s CM model as, if bilinguals process this information more quickly and easily, it is more likely that words are retrieved directly and are not taking more time to translate them as they would in the WA model.

The Study

Methodology

All 10 participants viewed a 66-second practice video and 98-second video using Windows Media player on a Dell laptop full screen in a quiet location to avoid distraction and recording errors. The video was produced on Windows Live Movie Maker and featured the instructions: ‘You will see a series of words. Please speak aloud the COLOUR of the word. Do not read the word itself. Try to answer as quickly and as accurately as possible.’ in black ink on a white background. This was the only instruction participants received so that no participant was given an advantage and so the amount of briefing each participant received could be controlled. Though participants found the instructions straightforward, doing the practice task with different combinations beforehand allowed them to better understand the procedure. It also allowed me to verify that both the audio from the video and from the participant was being recorded successfully. Once satisfied of this, the irrelevant practice data was deleted.

In both videos this was followed by a 3-second countdown before 20 words in the Practice Task and 40 words in the real task appeared sequentially onscreen, each appearing for exactly 2000 milliseconds accompanied by a synchronised metronome ‘tap’ noise. I recorded each participant using a Trust MC-1200 microphone and later analysed the sound clip using WavePad Sound Editor (v 4.52) to measure the time between each ‘tap’ (when the stimulus appeared) and the participant’s response (RT) in milliseconds. The colour words were written in uppercase Segoe UI font size 36 in capital letters, positioned in the same place in the middle of the screen, and were all examples of incongruent stimuli (Stroop, 1935). Nine colour words and seven colours of ink were used, as white and orange appeared indistinguishable on the white background (see Appendix C). It was important that the colours were easy to identify so that it would not result in unnecessary hesitation. The instructions, colour words, and responses from the participant were all in English.

Participants

In order to compare the reaction times I selected an equal ratio of bilingual to monolingual participants: 5:5, and to have fewer variables I used all female participants (Stroop (1935) found variation in male and female Stroop performance) all within a relatively narrow age range of 17-23 and an average age of 20.7 years. All participants were in full time undergraduate education except for Participant 5 who is due to enter into undergraduate study this year.

Two of the five bilinguals in the study (Participants 4 and 5) were simultaneous English-dominant bilinguals who spoke Cantonese to their parents, English outside the home and a mixture of both to their siblings. Participants 1, 6 and 7 were sequential bilinguals who used Mandarin Chinese as their dominant language at home and with friends and family and spoke and studied English at university, having learnt it later in life in an academic setting. All languages of bilinguals other than English were Chinese languages which share orthographical characters to ensure less variation.

Note on omissions and anomalies

I intended to use 40 words in each Stroop test but only analyse the data from 36 so as to allow for anomalous results to be omitted. For example, Participant 1’s reaction times roughly all ranged between 600-1000 milliseconds aside from two occasions: words 23, when she mistakenly said the wrong word, and 37, when she hesitated and first said ‘um’ before the colour. These errors strongly affected the correlation of the data, and so were deemed anomalous and removed. Although word 7 was only inhibited by a slight delay in comparison (1146ms) and word 2 was still within this range (998ms), they were still anomalous in the context of her adjacent reaction times and so were chosen as my third and fourth candidates for removal. Therefore only 36 of the 40 were used to ascertain her average response time. Correspondingly, from each participant I removed four anomalous times which did not conform to the trend of its surrounding data so as to acquire a more accurate result and more effectively compare the mean times. Omitting these two participants does not change the result (that bilinguals have a slower mean RT than monolinguals), but it gives both groups a faster mean RT and a greater difference between them (now 54.764ms as opposed to 19.539ms with all five participants).

Analysis

Before the omission of anomalies the mean reaction times per word of bilingual participants and monolingual participants demonstrated that 15 of the 40 words had a shorter average reaction time of bilingual participants, thus 62.5% of words were processed more quickly by monolinguals. After removing participants 4 and 9 only 9 words were processed more quickly by bilinguals, thus a 77.5% majority of words were processed faster by monolinguals (Appendix B).

Bilinguals performing the task in their dominant language (Participants 4 and 5) had a mean RT of 693.46ms, faster than the overall bilingual mean but not the monolingual mean (Appendix A). Figure 1 shows how close the mean RTs of each participant is; there is little disparity between monolinguals and bilinguals. It also shows the anomalous nature of Participant 9's results, who reacted much more slowly than her fellow monolinguals. Participant 4 is also shown to be anomalous though more subtly.

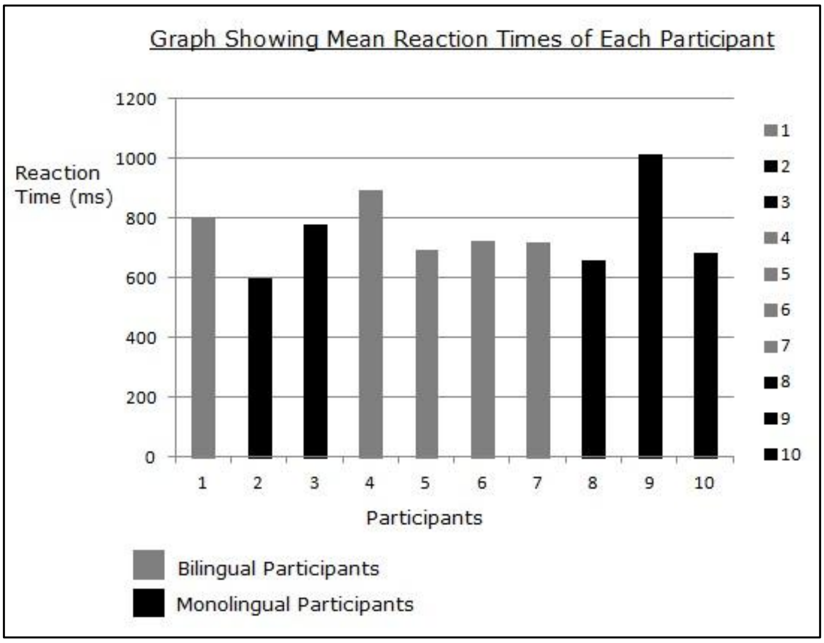

Figure 1. Mean Reaction Times of Participants.

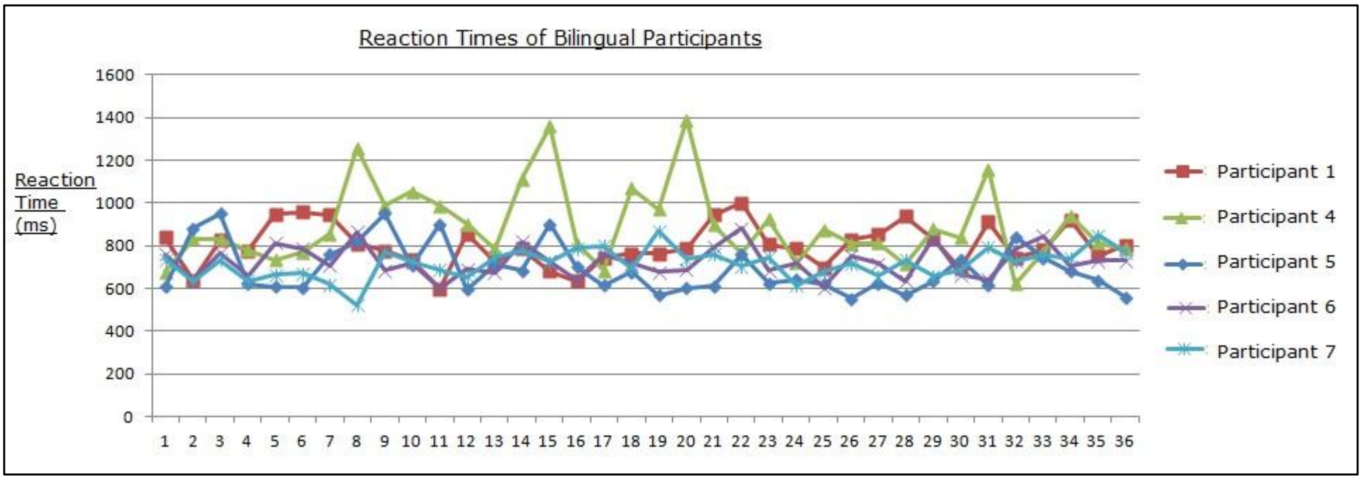

Figure 2. Reaction Times of Bilingual Participants. N.B.: Numbering on X Axis does not refer directly to word number as four anomalous reaction times have been omitted, leaving only 36.

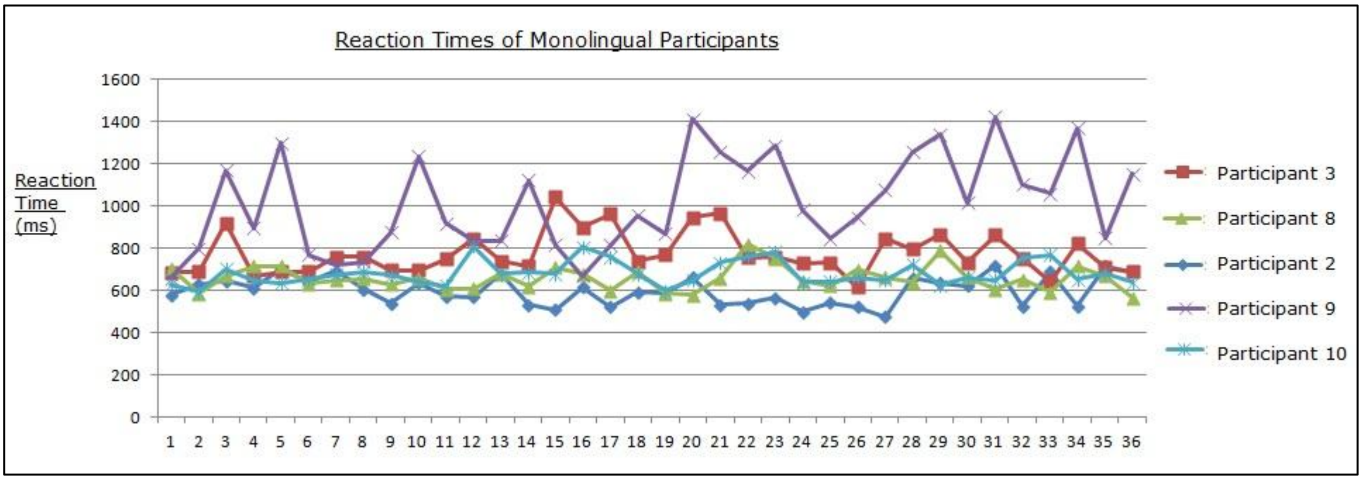

Figure 3. Reaction Times of Monolingual Participants. N. B. Numbering on X Axis does not refer to word number as four anomalous reaction times have been omitted, leaving only 36.

As you can see clearly from the scatter graphs Participants 4 and 9's data fluctuate considerably in comparison to the others who have a more reliable correlation, which is why I removed them from my overall bilingual and monolingual mean calculations.

Though monolinguals on average do have faster reaction times, the graphs clearly show that there is no great dissimilarity between the two as they mostly range between the 400-1000ms boundaries. The bilingual results also fall within this range, but have fewer RTs lower than 600ms.

In conclusion, the bilingual and monolingual results are very similar, but monolingual participants have shorter RTs on average.

Discussion and Conclusion

The study was expected to support the previous studies and suggest that bilinguals performed better than monolinguals in the Stroop task (Bialystok, 2001; Bialystok et al., 2004; Okuniewska, 2007; Bialystok et al., 2008; Van Heuven et al., 2011), but the mean RTs were in fact faster for monolinguals, so the data does not support the CM model. The kind of bilinguals used or the age of participants are factors which could account for this surprising result.

We would have expected to see faster times of English-dominant, simultaneous bilinguals because the Stroop task was in their L1 English which sequential bilinguals would find more challenging. Mandarin-dominant bilinguals had an average RT of 748.222ms, slower than Participant 5's mean of 692.86ms (4 was omitted, otherwise the mean would be 793.46ms), although this is not very reliable as it only includes one English-dominant simultaneous bilingual.

Participant 1 informed me afterwards that she would instantly think of the word for the colour in question in her L1 Mandarin Chinese, but then have to translate it into English, a considerable factor affecting her reaction time. This would be more indicative of the WA model than CM model, as the English colour word had to be accessed via mediation with its Mandarin equivalent. This phenomenon could have been better investigated if the experiment had consisted of four tests rather than one: one with English words answering in English, one with Chinese characters answering in English, one with Chinese characters answering in Chinese, and one in English answering in Mandarin or Cantonese, this would perhaps have been more illuminating as direct comparisons could be made between the languages. Moreover, the absence of a congruent Stroop test with which to compare the non-congruent data samples would have highlighted how much Stroop interference affected participants individually.

One proposed interpretation for why my results do not corroborate with the expected prediction is due to the fact that my bilingual participants are mostly non-English dominant, the language utilised exclusively by the task, and thus may have been more likely to translate as Participant 1 did. Research has shown that balanced bilinguals respond faster than unbalanced bilinguals in the Stroop task (Zied et al., 2004). The two English-dominant bilinguals were more balanced bilinguals than the others used in the study, and although one of the two produced anomalous results, the other produced the fastest bilingual mean time (693ms), which corroborates with Zied et al.'s findings.

Age of acquisition is another important factor, as sequential bilinguals (Participants 1, 6 and 7) had a longer delay before being exposed to their L2 and thus we would expect there to be greater input from their non-English language than the two balanced bilinguals of the study (Participants 4 and 5) (Harley, 2010: 84). Mägiste (1984) in her language proficiency hypothesis suggested that more balanced bilinguals would suffer less from the interference effect, and as Participant 5 does indeed have the fastest bilingual mean RT this would appear to corroborate. However, as previously mentioned, one example is not enough to base a definite conclusion on and more research would have to be done.

Another explanation for the data's inconsistency with existing research is due to the age range selected. Zied et al. (2004) found when studying old and young age groups of French-Arabic bilinguals that there was a correlation between age and diminished performance in the Stroop task, and Bialystok et al. similarly produced faster reaction times from younger participants in their Stroop task (2008). Ludwig et al.'s Stroop task also revealed that older participants had longer RTs than younger ones, who were able to resist the dominant response to read the word more easily (2010). Because of this research I decided to select participants of a close age range so as not to receive a range of times which could be attributed to their age, but selecting a number of older participants in addition would have perhaps featured fewer capable monolinguals.

Okuniewska (2007) finds the 20-29 age range to be optimal for efficiency in this area, and Bialystok et al. similarly found that bilinguals were faster in the Simon task in all age groups except for in the category of young adult (20-30 years, in which all but one of my participants fall), where monolinguals and bilinguals produced equal RTs. Furthermore, high intellectual level as well as age has been shown to contribute to better performance in the Stroop task (MacLeod et al., 1991). As my participants' mean age was 20.7 years with a range of 17-23 years, and in full-time education, they are arguably in optimum condition for doing the Stroop task and thus both monolinguals and bilinguals would perform well regardless of the number of languages spoken. My faster monolingual times may therefore be explained by their young age and level of education, and to investigate this further more age groups would have to be involved in the study.

In conclusion, although the study did not provide evidence for the CM model of language processing, this I feel is probably due to the simplicity of the experiment and the narrow range of participants featured. Combining this with different age groups and different intellectual levels would have been more illuminating. Moreover, Stroop Facilitation (1935) by way of congruent colour examples would also have been useful in order to determine the individual differences and provide a non-conflicting point of comparison.

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Appendices

A. Experiment Results:

Entries in red have been viewed as anomalous and omitted and not used in calculating mean RTs. Participants 4 and 9 were also omitted due to anomalous fluctuations in data, and so are not included in Bilingual and Monolingual RT means.

Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mono/bilingual	B	M	M	B	B	B	B	M	M	M
Age	22	22	22	20	17	21	23	20	20	20
Gender	F	F	F	F	F	F	F	F	F	F
First Language (L1)	Mandarin & Cixi Dialect Chinese	English	English	English	English	Mandarin Chinese	Mandarin Chinese	English	English	English
Second Language (L2)	English	-	-	Cantonese Chinese	Cantonese Chinese	English	English	-	-	-
Reaction Time (ms) **1**	840	789	685	679	607	760	738	707	658	631
2	998	579	691	831	882	1077	636	586	801	592
3	637	630	921	833	951	639	733	974	1171	703
4	827	645	669	780	623	767	636	670	898	649
5	777	507	688	734	609	658	665	716	1299	637
6	949	614	688	770	966	814	671	715	769	654
7	1146	699	761	856	606	788	617	634	720	676
8	959	638	761	1259	761	708	523	649	737	848
9	945	1112	1175	989	821	973	774	657	876	689
10	810	693	697	1052	950	865	727	631	1236	674
11	776	607	695	987	707	683	686	658	919	643
12	734	539	751	903	901	719	654	606	836	622
13	600	637	1050	788	595	603	747	610	837	811
14	856	574	847	1113	713	690	780	679	1124	681
15	725	569	740	1361	683	676	725	621	1457	687
16	786	681	717	1607	903	821	791	709	816	680
17	681	532	1042	808	701	726	1432	681	669	805
18	636	510	900	684	615	637	948	600	815	760
19	744	616	962	1070	679	759	800	688	955	679
20	764	522	738	1594	570	718	694	586	871	600
21	762	594	768	970	602	677	869	578	1415	651
22	788	590	947	1391	611	688	737	659	1257	734
23	1970	663	968	1570	761	792	936	1049	1166	764
24	946	533	756	900	1212	883	761	820	1286	782
25	1000	539	759	763	626	685	703	753	984	640

26	805	565	729	924	642	720	746	645	845	644
27	788	501	733	722	622	606	614	624	573	663
28	697	542	617	1512	552	754	677	701	945	651
29	829	524	845	875	624	716	716	664	1075	723
30	853	476	795	811	570	634	658	641	1257	627
31	939	660	868	812	1482	835	735	789	1341	868
32	832	637	1194	714	636	1264	659	936	1016	663
33	694	622	732	878	738	666	685	664	1425	651
34	912	835	863	840	616	641	793	607	1104	884
35	743	721	752	1158	843	783	726	653	1059	755
36	780	525	642	623	462	535	1088	593	711	771
37	1331	691	823	769	743	846	756	716	1369	1014
38	920	526	709	940	682	705	742	671	1762	653
39	753	716	690	813	638	731	849	566	850	682
40	803	691	1107	786	560	732	770	759	1154	641
Mean (After Omissions of data in red)	**802.5**	**600**	**776**	**894**	**693**	**726**	**716**	**660**	**1015**	**682**
Bilingual Mean RT (Participants 1, 5, 6 & 7)	**734.382**	Mean of All Bilingual Participants (1, 4, 5, 6 & 7)	766.317							
Monolingual Mean RT (Participants 2, 3, 8 & 10)	**679.618**	Mean of All Monolingual Participants (2, 3, 8 & 10)	746.778							

B. Mean Times Per Word
N.B. Averages calculated before omission of anomalies in red, but not including participants 4 and 9).

Word	Bilingual Mean Time	Monolingual Mean Time	Shorter Reaction Time
1	736.25	703	M
2	898.25	612	M
3	740	807	B
4	713.25	658.25	M
5	677.25	637	B
6	850	667.75	M
7	789.25	692.5	M
8	737.75	724	M
9	878.25	908.25	B
10	838	673.75	M
11	713	650.75	M
12	752	629.5	M
13	636.25	777	B
14	759.75	695.25	M
15	702.25	654.25	M
16	825.25	696.75	M
17	885	765	M
18	709	692.5	B
19	745.5	736.25	M
20	686.5	611.5	M
21	727.5	647.75	B
22	706	732.5	M
23	1114.8	861	M
24	950.5	722.75	M
25	753.5	672.75	M
26	728.25	645.75	M
27	657.5	630.25	M
28	670	627.75	M
29	721.25	689	B
30	678.75	634.75	B
31	997.75	796.25	M
32	847.75	857.5	B
33	695.75	667.25	B
34	740.5	797.25	B
35	773.75	720.25	M
36	716.25	632.75	B
37	919	811	B
38	762.25	639.75	B
39	742.75	663.5	M
40	716.25	799.5	B

C. Stroop Task Answers

	Answer	Word Written

1	**RED**	WHITE
2	**GREEN**	BLACK
3	**RED**	ORANGE
4	**BLUE**	RED
5	**YELLOW**	RED
6	**GREEN**	ORANGE
7	**BLACK**	BLUE
8	**PINK**	BLACK
9	**GREEN**	PURPLE
10	**BLUE**	YELLOW
11	**PURPLE**	GREEN
12	**YELLOW**	BLUE
13	**RED**	YELLOW
14	**PURPLE**	YELLOW
15	**BLACK**	GREEN
16	**GREEN**	WHITE
17	**GREEN**	PINK
18	**RED**	PURPLE
19	**PINK**	RED
20	**BLUE**	RED
21	**BLACK**	YELLOW
22	**RED**	ORANGE
23	**BLUE**	GREEN
24	**GREEN**	WHITE
25	**YELLOW**	BLUE
26	**PINK**	BLUE
27	**PINK**	BLACK
28	**BLUE**	WHITE
29	**PINK**	RED
30	**YELLOW**	PINK
31	**PURPLE**	RED
32	**RED**	BLUE
33	**PURPLE**	BLUE
34	**BLACK**	PURPLE
35	**RED**	ORANGE
36	**RED**	GREEN
37	**GREEN**	BLUE
38	**BLACK**	WHITE
39	**PURPLE**	GREEN
40	**RED**	YELLOW

D. Sound clips (x10) of participants' Stroop Task.

E. Videos (x2) of Practice Stroop Task and Stroop Task used.